Growth, Factor Shares, and Factor Prices

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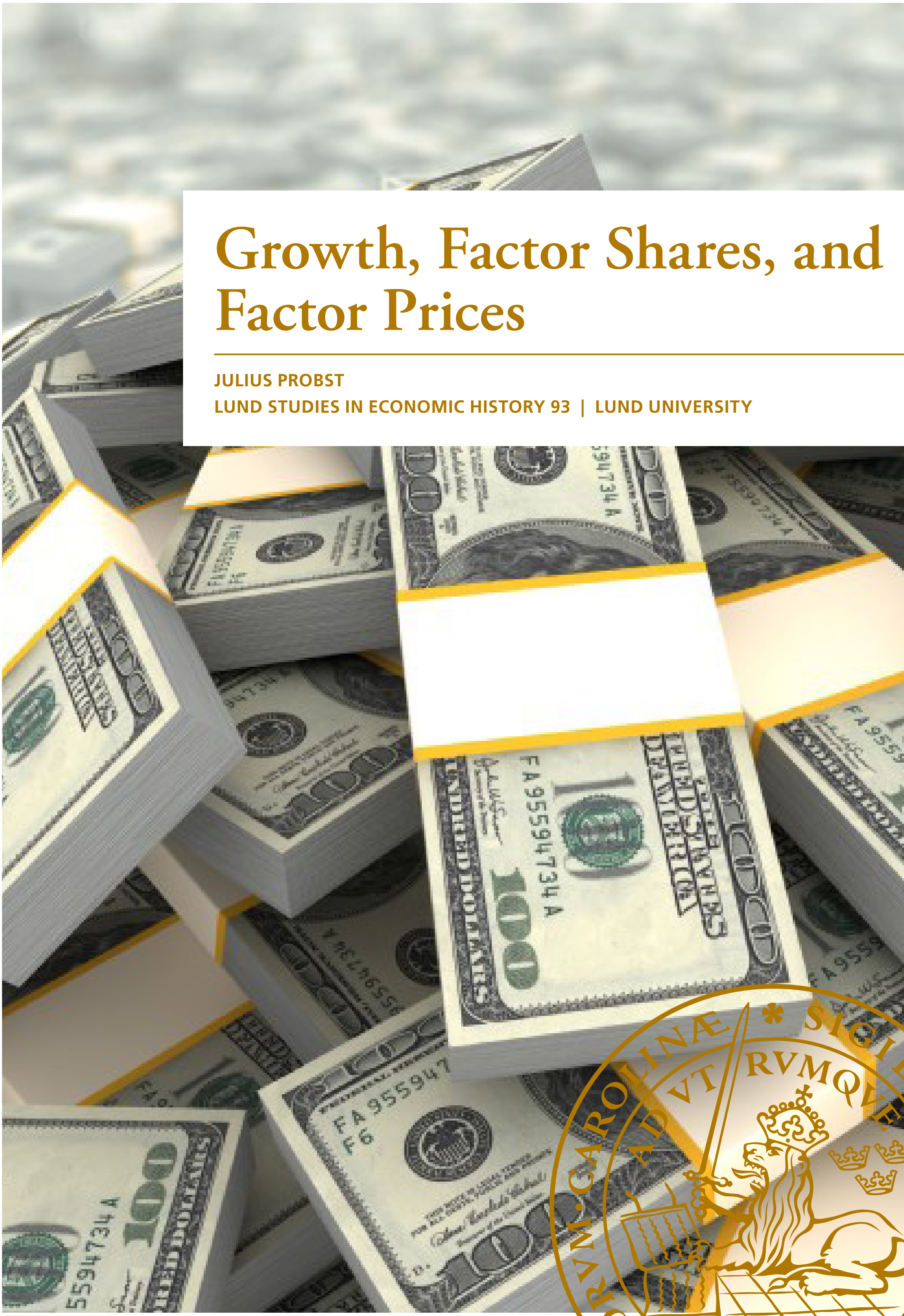

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JULIUS PROBST

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Growth, Factor Shares, and Factor Prices

Julius Probst

DOCTORAL DISSERTATION

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Abstract

This dissertation is a study in empirical macroeconomic history. The first two papers concern themselves with the functional distribution of income. The third paper is an examination of global real interest rates, and the final paper examines city growth in Sweden over the last two hundred years. While this thesis is not about secular stagnation per se, every articles is related in one way or the other to Larry Summers' theory.

The Kappa discusses in greater length the theory of secular stagnation and the related macroeconomic phenomena that have ailed advanced economies in recent years, including low real interest rates, higher debt levels and equity prices, and rising inequality, including lower labor shares.

The first paper of the thesis examines the downward trend in the US labor share since the postwar period. We establish that a significant part of the decline is related to rising imputations in the GDP caluclations. More specifically, economy-wide depreciation and imputed rents have increased substantially in recent years.

The second paper uses long-run panel data for 17 advanced economies and establishes a relationship between rising asset prices and the increasing capital share of GDP. We find a signficant effect of stock price booms on the capital share. The relationship for housing booms is weaker.

The third paper of the thesis exmines global real interest rates for the same set of advanced economies from 1870 to today. Using a time series factor model, we establish that a substantial part of the variation in real interest rate is determined by global factors. In contrast to neo-keynesian models, this finding implies that Central Banks have less monteary autonomy than what is commonly assumed.

Finally, the last paper examines Swedish city growth from the pre-industrial period to today. We estimate Zipf's law for each decade from 1810 to 2010. Using the rank-size rule as a bechmark, we also show that, with the exception of Stockholm, most large Swedish cities are considerably smaller than what the power law would suggest. Given the positive relationship between city size and productivity, this finding might even have macroeconomic implications.

Secular stagnation; labor share; imputations; asset prices; real interest rate; Zipf's law

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I dedicate this thesis to my shining light Jess Saade and my family, especially my parents.

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Finally, I would like to acknowledge the Stoics, especially Epictetus and the Roman emperor Marcus Aurelius, whose words have proven to be a useful guide and whose principles I aim to live by: Amor fati!

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Disclaimer

The author Julius Probst is currently a PhD trainee at the European Central Bank. The views expressed here are those of the author and do not necessarily represent the views of the European Central Bank and the Eurosystem. This work was done prior to the author's affiliation with the ECB.

List of papers

I Probst, Julius (2019). The decline of the labor share, depreciation, and imputed housing costs. *Unpublished manuscript.*

II Probst, Julius (2018). Financialization, asset prices, and the functional distribution of income: A long-run cross-country analysis. *Unpublished manuscript.*

III Probst, Julius (2019). Global real interest rate dynamics from the late 19^{th} century to today. *International Review of Economics and Finance (59), pp.522-547.*

IV Probst, Julius (2017). Zipf's law for Swedish cities from 1810 to 2010. *Unpublished manuscript.*

Introduction

Aim and motivation

This thesis is a study in empirical macroeconomic history. We devote our attention to the economics of growth and the determination of factor shares and factor prices. Growth and inequality are obviously among the most important topics in the field of macroeconomics. The literature dates back to Adam Smith who already examined in in his influential work "The Wealth of Nations" published in 1776 why some economies are rich while others are poor (Smith, 1776). Even today, the topics of economic growth and inequality are at the forefront of the macroeconomic research agenda (Galor and Zeira, 1993; Bertola, 2000; Piketty, 2014). More recently, Larry Summers has revived the theory of secular stagnation, which was originally put forward by Alvin Hansen in the late 1930s (Hansen, 1939; Summers, 2015). Summers (2015) argues that a number of structural factors have led to a significant decline in real interest rates across most advanced economies in recent decades. These secular forces include declining productivity growth, rapidly ageing and even shrinking populations, and rising inequality. Secular stagnation refers to the peculiar condition where the interest rate that is required to balance aggregate demand and aggregate supply is negative. Given that nominal interest rates are constrained by the so-called effective lower bound (ELB), advanced economies might suffer from a semi-permanent economic slump as a result of insufficient spending (Summers, 2014; Summers, 2015). While this thesis is not about secular stagnation per se, the attentive reader will notice that all four papers discuss research topics that are in one way or the other intrinsically linked to Summers' theory. In this study, we try to contribute to the debate on growth, factor prices, and factor shares with an extensive analysis of macroeconomic history data.

The distribution of income gains and the extent of inequality within economies is obviously one of the more important topics within the field of macroeconomics (Piketty, 2014). More recently, a large number of studies have looked into the evolution of the functional distribution of income

(Atkinson, 2009). While economists, in general, have focused more on the last few decades (Karabarbounis and Neiman, 2013), some economic historians have taken a long-run approach and gathered data spanning back to the late 19th century (Bengtsson-Waldenström, 2015), and even prior to that (Piketty, 2014). The aforementioned research has emphasized that, contrary to the assumption of the very basic long-run growth models like the neoclassical Solow model (Solow, 1956), factor shares can actually fluctuate quite wildly, both in the short-run and in the medium to long-run (Piketty, 2014).

Two of the research papers of this thesis are devoted to the study of the functional distribution of income, and more specifically, how and to what extent asset price movements affect the capital share of GDP. Here we already find the first link to the secular stagnation debate. The long-term decline in global real interest rates that has taken place since the late 1990s also had a huge impact on global asset prices (Summers, 2014). The value of any financial asset is determined by its future discounted cash flows (Sørensen and Whitta-Jacobsen, 2005). The decline in interest rates thus had the side effect of boosting asset prices across the globe, given that all future cash flows are now discounted with a lower rate. This trend also seems to have affected the functional distribution of income by increasing the capital share of GDP.

The first paper of the thesis focuses on the US experience using BEA data for the postwar period. We examine the national income and product accounts (NIPA) in more detail, with a special emphasis on depreciation rates by sector as well as by asset class. While economy-wide depreciation rates have increased quite significantly from the postwar period until today, there seems to be very little acknowledgement of this evolution in the macroeconomics literature, even though this is potentially a very important trend. Real growth rates, for example, might be even lower than assumed if countries have to devote a larger fraction of GDP simply to replace obsolete capital. Furthermore, we also study the evolution of imputed rents, which again is an extremely relevant topic given the large secular boom in house prices across advanced economies in the period post Bretton Woods. There is a case to be made that secular stagnation might have contributed to the two phenomena just mentioned above. Imputed rents are clearly a function of aggregate house prices, which in turn have been affected by the long-term decline in interest rates. Similarly, the depreciation share of GDP might also increase if asset prices are rising faster than GDP for a considerable time period, as it has been the case in recent decades (Jorda et al., 2017a).

The second paper examines the effect of asset price booms on the capital share, using long-run historical panel data spanning back to the late 19th century. More specifically, we examine to what extent growth in stock prices and growth in house prices affect the capital share of GDP across a panel of 17 advanced economies.

Of course, any study on the evolution of factor shares must also be accompanied by an analysis on how factor prices are determined, with the real interest rate being one important factor price, namely the price of capital. In today's global economy, many factor prices are set in international markets, given that national economies are increasingly intertwined by global trade and capital flows. This is especially true for real interest rates, as they are determined by international financial conditions in global financial markets (Jorda et al., 2017a; Jorda et al., 2017b).

Our third study examines the behavior of real interest rates across a panel of advanced economies from the late 19th century to today. We show that real interest rates across advanced economies are to a very large extent determined by one common global factor variable. This obviously begs the question to what extent policy makers, and especially monetary policy makers, have autonomy after all. While Central Banks are assumed to have reasonable control over the domestic rate of inflation and nominal GDP growth (Sumner, 2014), it is much less clear whether they can actually determine the real interest rate even in the short-run, especially when capital mobility is high. Our factor model approach shows that a significant fraction of the variation in real interest rates is determined on the global level, and thus outside the influence of domestic policy makers, unless you are the Fed and therefore provide liquidity to the entire global financial system (Beckworth and Crowe, 2012). Furthermore, we also extract the global real interest rate from our factor model and confirm the long-run downward trend that has taken place in recent decades, thus corroborating Summers' theory of secular stagnation (Summers, 2014).

Finally, the last paper of the thesis is related to the economics of growth. More specifically, we examine city growth rates in Sweden over a time period of 200 years and examine the rank-size distribution of the Swedish city network. While there is no clear and apparent link to secular stagnation at first, it should be noted that increasing agglomeration effects have aggravated the real house price booms that has taken place on global scale in recent decades, thus contributing to rising asset prices (Moretti, 2012).

Historically speaking, economic growth is of course very closely linked to urbanization, which has played a crucial role in the development of human societies ever since the early Antiquity (Morris, 2010; Temin, 2012). Here we encounter the idea that human development depends on urban size and population levels. Specialization and trade across regions only make sense beyond a certain population threshold. Infrastructure development, bureaucracy, military power, and many other aspects of economic development also scale up (Bettencourt et al., 2007; West, 2017). Rome, and Roman cities, already had developed enormous infrastructure projects, from public baths, to aqueducts, and coliseums, building fortified cities and an extensive road network across the European continent and beyond, with many of these public projects being way more impressive in size and scale than what came during the period of the Middle Ages thereafter. During the late Middle Ages, the economic and political center of gravity started to shift from the Mediterranean northwards to the Baltic Sea and the Atlantic Ocean. Innovations in shipbuilding and navigation during the Renaissance period allowed for European explorations beyond the Atlantic to the "New World", and around Africa to South East Asia and Oceania (Pomeranz, 2009). While there were certainly a multitude of factors that allowed Europe to gain an edge (economically and military) over other societies and cultures, the competitive arms race that followed these new discoveries certainly contributed as well. The territories that were occupied overseas and the resources that flew back to Europe contributed to economic development, and Great Britain benefitted the most, thanks to her advantageous geographic position (Pomeranz, 2009). London was thus the first city to reach a population level of one million again in the early 1800s during the early Industrial Revolution, almost two millennia after this threshold was first crossed by Rome (Morris, 2010). Urban development has therefore been closely linked with economic growth in general (De Vries, 2006), Many studies have confirmed the virtuous cycle between urbanization and agglomeration economies (Quigley, 2009) that led to important productivity gains and industrialization (Allen, 2009), thus further contributing to rising population growth in the cities (Boserup, 1981).

While the size of the primate city is certainly one contributing factor to a country's economic development (Berry, 1961; Rosen and Resnick, 1980), the characteristics of the entire city network and its dynamic behavior over time are certainly of crucial importance as well. More recently, urban economists have started to study in greater detail the urban hierarchy with a particular focus on the so-called rank-size relationship, an empirical regularity that describes how city rank and city size are related to each other (Krugman, 1996). While there are many studies using more contemporaneous data (Gabaix, 1999a; Gabaix, 1999b; Venables, 2005), more recently some economic historians have also estimated the relationship for the early modern period in Europe (Dittmar, 2011; Gonzalez-Val, 2017).

Sweden was still a relatively poor and also extremely sparsely populated country at Europe's periphery in the early modern period, with the largest Swedish cities barely reaching a population level of a few thousand inhabitants during the Renaissance period (Schön, 2010). Industrialization reached the country only by the end of the 19^{th} century, and therefore a few decades after it had started in continental Europe. Furthermore, Sweden's geographic size combined with its low population density implied that the industrial development was actually somewhat rural in nature, thus also reaching many small towns in the more sparsely settled parts of the country (Schön, 2010). While Sweden might be a little bit of an outlier in terms of its industrial development, it is still a very interesting case study. Thanks to the richness of historical sources and population figures for Swedish cities, we can study her population dynamics over the course of two centuries, using detailed city population data from 1810 onwards. While extrapolation from one case study is always a somewhat risky and difficult affair in the field of social sciences, we believe that understanding some of the dynamics of Swedish city growth can be illuminating, not only on its own but also within the more general context of industrialization and economic development of an overwhelmingly rural and extremely poor economy at Europe's periphery during the early modern period.

Research questions

The thesis consists of four different papers, which touch on different macroeconomic topics. We will therefore list the title of the papers with the research question of each article in the following section:

Paper 1: The decline of the US labor share, depreciation, and imputed housing costs

This paper investigates the link between the so-called factorless income streams and the capital share of GDP, using data for the postwar period for the US economy. More specifically, the paper addresses the following research questions:

1. To what extent is the decline in the labor share simply a result of rising imputations in the GDP calculations?

2. Are depreciation rates increasing over time and which sectors and asset classes are affected the most?

3. Are imputed rents increasing over time and how does this affect the labor share?

The main aim of this study is thus to investigate to what extent rising depreciation rates as well as imputed rents have affected the gross capital share in the US in recent decades. Furthermore, we decompose depreciation rates by asset class as well as by industry. The purpose of this exercise is to find the specific drivers of the increasing depreciation share in today's economy. We also aim to establish whether the rising depreciation is merely an accounting concept for firms and businesses or whether it reflects the true economic costs of the depleting capital stock.

Paper 2: Financialization, asset prices, and the functional distribution of income: A long-run cross-country analysis

The second paper concerns itself with the functional distribution of income, using a long-run panel data approach over a time period from the late 19th century to today. More specifically, we aim to investigate the link between rising asset prices and the capital share of GDP, thus addressing the following research questions:

1) To what extent are rising stock prices and rising house prices affecting the capital share of GDP in the short to medium run?
2) How has this relationship changed over time?

We therefore investigate the link between rising stock prices and rising house prices and the functional distribution of income across our panel of 17 advanced economies by estimating short and medium run elasticities of asset price growth on the capital share of GDP.

Paper 3: Global real interest rate dynamics from the late 19th century to today

This paper uses global real interest rate data for the same panel of 17 advanced economies from 1870 until today. The main research questions of this study are the following:

1) To what extent are real interest rates determined by global vs. national factors?

2) How do the global monetary regime and the international macroeconomic environment affect whether interest rates are predominantly determined by global factors?

The aim of this paper therefore is to identify whether real interest rates are mostly determined by global factors, which is in contrast to what most conventional macroeconomic models assume. Moreover, we also investigate for which time period this consideration is especially prevalent.

Paper 4: Zipf's law for Swedish cities from 1810 to 2010

This last paper examines Swedish city growth over the time period from 1810 to 2010, using Zipf's law as a benchmark. The paper addresses the following research questions, which are:

1) How did the Swedish city network develop over time?
2) To what extent does the estimated Zipf's law coefficient for Sweden fluctuate over the last 200 years and how did modern economic growth, starting with the Industrial Revolution, affect the rank-size distribution in Sweden?
3) Is there evidence for rising population concentration on the national level in recent decades?
4) To what extent do cities in Sweden deviate from the so-called Zipf-consistent estimate in terms of their actual population size and what are the implications?

This research thus aims to identify the evolution of the Swedish city network over time, using Zipf's law as the benchmark case.

Limitations

The first paper of the thesis discusses the decline in the US labor share during the postwar period. We analyze several macroeconomic aggregates, from the economy-wide depreciation rate to imputed rents as a share of GDP. We also decompose depreciation rates by sector as well as asset class. While we mostly focus on the US experience, we also add some international evidence on how depreciation rates have risen across all advanced economies during the time period under consideration.

The second paper examines fluctuations in the functional distribution of income, using data from 17 advanced economies from about 1875 to today. While the primary focus of the paper is to establish a link between asset prices and the capital share of GDP, we also use a range of other macroeconomic variables as control variables in our estimation methods, which we will discuss in more detail below.

We use the same dataset for the third paper in the thesis in which we examine fluctuations in the real interest rate for the same set of advanced economies. While the small sample size is to some extent a restriction for our analysis at hand, we partially recover from this by having very long macroeconomic time series data that stretches back to the late 19th century. Of course, this also introduces other problems, such as several macroeconomic regime changes that have taken place in terms of the global monetary system (Eichengreen, 1998).

The last paper of the thesis examines Swedish city growth from 1810 to today, using 200 years of Swedish population data coming from two main sources: the Folknets database for population date from 1810 onwards and the Swedish Statistics office SCB. While during the early modern period Sweden was an empire in the Baltic region, stretching from Northern Germany and Poland, to Norway and Finland, our analysis of the city network exclusively focuses on all Swedish cities within the contemporaneous geographic boundaries of the country from 1810 onwards. This choice was mostly made for data availability reasons, given that the population data coverage for Swedish cities during the early modern period lying outside of contemporaneous Sweden is rather sporadic.

One should be aware that for the purpose of this thesis we have focused on a rather exclusive set of advanced economies, which all started to industrialize more than a century ago. While each of these nations has their own particular history, culture, and country-specific institutions, they share many more common denominators amongst each other than compared to emerging markets and other low-income countries.

One should thus be aware of the limitations of these studies when it comes to the extrapolation of our findings, not only with regard to a different set of countries, but also with respect to future trends. As we all know from the study of economics and economic history, being a social science, institutions and social context matter a great deal (Acemoglu and Robinson, 2013). While there are some fundamental economic laws that do hold like gravity, the gravity equation (Feeenstra et al., 2001) and the rank-size distribution (Krugman, 1996) being two such examples, we certainly deal with evolving societies. Economic relationships therefore evolve along with changes in institutions and the socio-economic environment (North, 1971).

While we are aware of some of the limitations of our study just mentioned above, we hope to make an important contribution to the field of economic history by testing a number of macroeconomic theories with the data and research methodologies at hand.

Definitions and fundamental concepts

The first three papers of the thesis concern themselves with the determination of factor shares and factor prices. The gross labor share is defined as the total wage compensation in the economy as a share of gross domestic output (GDP). The gross capital share is then often simply measured as the residual. However, there are certainly some flaws to this particular method, given how GDP is actually calculated. More specifically, factorless income streams, such as imputed rents and capital consumption allowance are also part of GDP (see figure 1).

GDP	Employee compensation
	Proprietor's income
	Net foreign factor income
	Corporate profits
	Interest payments & investment income
	Imputed rents & rental income
	Indirect business taxes
	Depreciation

Figure 1:
GDP and its subcomponents

GDP = labor income + capital income + economic rents

$$Y = w * L + r * K + \pi$$

Imputed rents, defined as the rent a homeowner would pay to him/herself, are included as housing services in the national accounts. They are commonly based on the home equivalence method, meaning that owner-occupied dwellings are benchmarked against their rental equivalent units (in terms of size, age, quality, geographic location, etc.). Capital consumption allowance, also known as depreciation of fixed assets, is counted as a cost of production and therefore included in GDP as well. While in theory it is certainly possible to split up GDP into three different factor returns, labor income, capital income, and economic rents, in practice the distinction between the pure rental rate and pure economics profits based on market power is actually infeasible. It is, for example, relatively hard to distinguish between Apple's return on capital and its monopoly profits based on its unique products. While some studies have tried to estimate markups by industry (Barkai, 2016; Gutierrez, 2017), the methodology relies on some questionable assumptions when estimating the rental rate of capital, thus casting some doubt on the accuracy of the presented calculations.

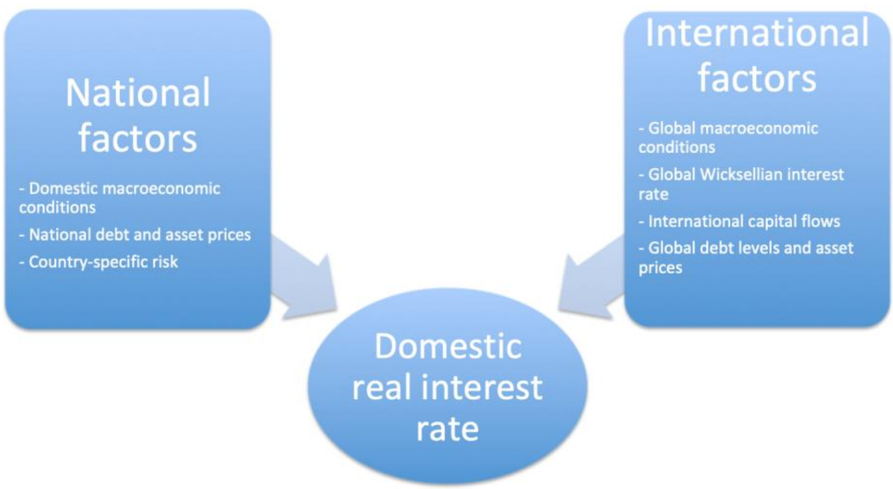

Figure 2:
The determination of the national real interest rate (small-country assumption)

The third paper concerns itself with the determination of the inflation-adjusted interest rate (the real interest rate) across advanced economies. Figure 2 below displays some of the key factors that can influence real rates within an economy, domestic macroeconomic conditions on the one hand, and international macroeconomic factors on the other hand. While the small country assumption rightly assumes that world macroeconomic conditions and the global real interest rate are given, this assumption is surely violated for the US economy, which as of today still assumes some 20% of global GDP (down from more than 30% in the intermediate postwar period). Many studies have shown that the Federal Reserve is the ultimate provider of global liquidity, given that a significant share of trade and financial products are priced in dollars and where many emerging markets have adopted some kind of dollar peg (Eichengreen, 1998). The Fed is therefore influencing monetary and financial conditions on a global scale (Beckworth and Crowe, 2012), and macroeconomic conditions in the US certainly seem to have an impact on the global real interest rate. While the same can be said to a lesser extent for the Eurozone, the ECB's interest rate tends to follow the US rate with a lag of about one to two years, meaning that the ECB is more likely playing the role of the passive follower rather than being an active participant in shaping global monetary conditions.

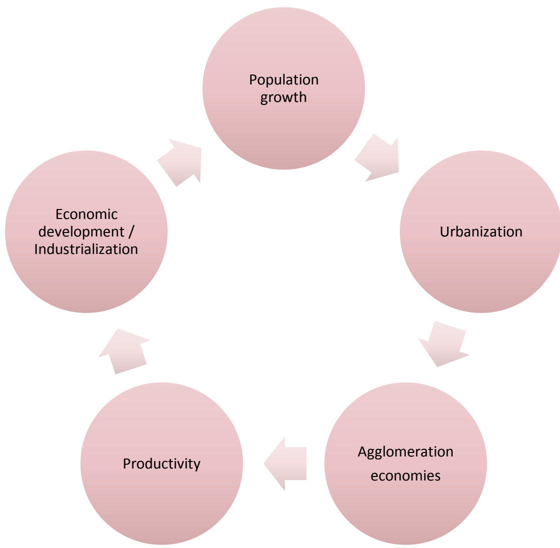

Figure 3:
The relationship between urban growth and economic development

Finally, the last paper concerns itself with the city size distribution and city growth in Sweden. Power laws are relatively common in economics and describe a fundamental proportional relationship between two variables (Gabaix, 1999a). Bettencourt et al. (2007), for example, have found that many infrastructure related variables scale with population size in a very specific way. The rank-size rule has been observed for many distinct phenomena and describes the relationship between a city's rank by population size in the city network and its population level. The relationship obeys a power law, with a slope coefficient equal to one in many cases (Krugman, 1996), meaning that the second city in the network is roughly one half of the size of the first, the third city roughly a third of the size, and the n^{th} city about 1/n the size of the primate city (Venables, 2007).

Figure 3 displays some fundamental relationship between urbanization, city growth rates, and economic development. Urbanization rates increased dramatically during the time period of the Industrial Revolution, which in turn led to further economic development and contributed to economic growth (De Vries, 2006). However, there certainly is some bidirectional causality involved here as well, since industrial development and increasing agglomeration economies in turn also led to further urbanization. All of these factors then shaped and influenced the city network as well as the rank-size distribution. As Klein and Leunig (2015) show for Great Britain, the Industrial Revolution was a period of unprecedented economic development compared to the previous decades, which also led to fundamental changes to the urban network in the British case.

Economic historical context

Sweden from the early modern period to today

While Sweden was a relatively poor country in the early modern period, it was at the same time a large military power in the Baltic region. By the end of the 16^{th} century, the Danish occupation of Southern Sweden (Skaneland) had ended as a result of a military conflict that lasted for several decades. During the so-called Age of Empire in the 17^{th} century, the Swedish empire was extended to Northern Germany, Northern Poland, and parts of Finland and Norway as a result of several wars, especially during the reign of Gustav Adolf. Living standards in Northern Europe at the time were relatively low compared to some continental and Southern European countries (Maddison, 2004). The graph below shows that Swedish real income per capita stagnated for most of the period from the 16th century to the early 19th century (Edvinsson, 2005; Enflo et al., 2014; Enflo and Missiaia, 2018). While the period of the Industrial Revolution started in the UK in the late 18th century and reached the continent by the early 19th century, Sweden was a relative latecomer to the Industrial Revolution, being located at the periphery of continental Europe (Schön, 2010). It should be noted that Sweden was an overwhelmingly rural and agrarian economy with an urbanization rate of less than 10% in the early 1800s (Heckscher, 1954). The introduction of the potato (Berger, 2018) and some other economic factors led to rapid population growth starting in the early 19th century, which allowed the country to escape from the Malthusian equilibrium in the pre-industrial era. Globalization and industrialization in continental Europe combined with domestic financialization and rapid deposit growth pushed the country on its path towards economic modernization in the late 1800s (Ögren, 2009). The two graphs below show that per capita income only started to edge upwards by the middle of the 19th century. Furthermore, Swedish industrialization was also somewhat rural in nature, given Sweden's large geographic size combined with its low population density. As a result of Sweden's low income levels compared to other European nations, the country did benefit to some extent from the advantages of backwardness (Abramovitz, 1986). Rapid industrialization and economic development in the late 19th century therefore initiated a period of rapid catch-up growth relative to Western Europe, a result of several factors that allowed Sweden to grow quite rapidly and turn a largely agrarian society into an industrial nation. Urbanization rates increased rapidly and population growth accelerated during the process of industrialization (Schön, 2010). The country's population increased from a mere 2 million in 1800 to more than 10 million by 2010. While there certainly have been some major fluctuations in the long-run growth rate on a decennial basis, one can see that a simple linear trend of real GDP per capita from 1850 to 2010 delivers a trend line of exactly 2%. While this fact at first seems to dismiss the theory of economic cycles suggested by Schumpeter (1961) and others (Forrester, 1977), it should be noted that decennial fluctuations in growth rates do exist, not only on the country but also at the global level (Maddison, 2004). Sweden, for example, experienced a relatively high average per capita GDP growth rate during the immediate postwar period, which corresponded to the postwar boom in continental Europe when countries recovered from the shocks of World War II. The 1970s, on the

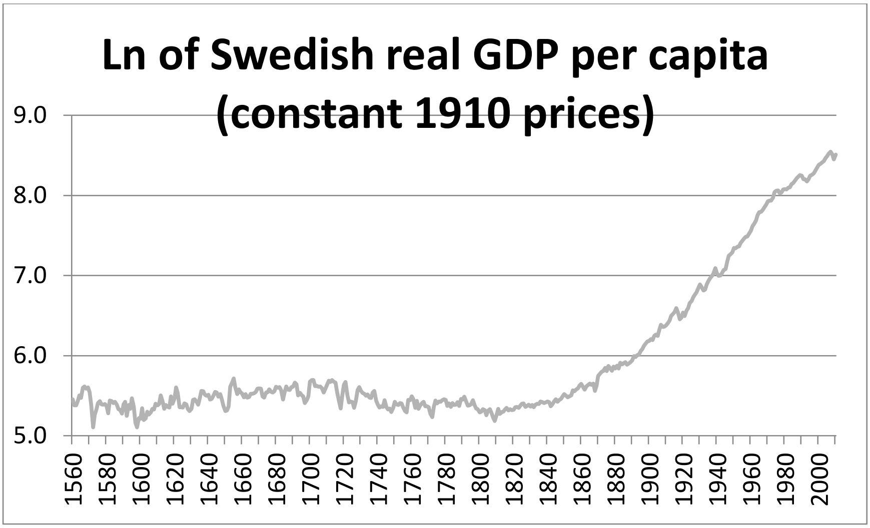

Figure 4:
Swedish real GDP in logarithms since the early modern period
Source: Enflo and Missiaia (2018); Enflo et al. (2014)

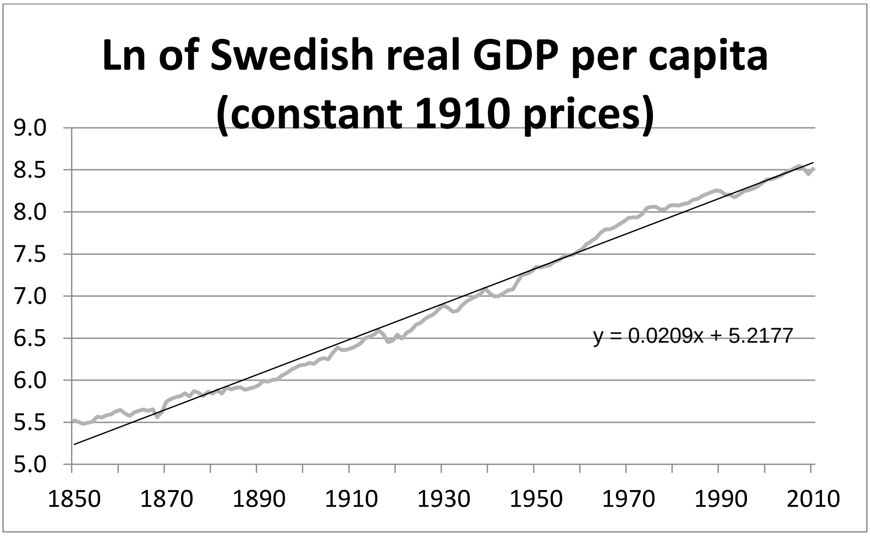

Figure 5:
Swedish real GDP in logarithms since 1850 with linear trend
Source: Enflo et al. (2014)

other hand, were a period of relative stagnation as the oil shocks led to a global negative supply shock. During the 1990s, Sweden and some other European countries followed the US lead and experienced relatively high productivity growth again as a result of the Dot-Com bubble and the associated boom in ICT technologies (Gordon, 2017) dor which Nordic countries had a relative lead vis-a-vis continental Europe in general (Oulton, 2012). During the early 1990s, Sweden also experienced a domestic financial crisis based on an asset price bubble. After a period of rapid financial liberalization, both house prices and stock prices experienced runaway rapid price increases (Englund, 2015). Given that the Swedish Kroner was pegged to the Deutsche Mark within the European Exchange Rate Mechanism (ERM), the Riksbank was unable to conduct monetary policy autonomously (Englund, 2015). After the asset bubble burst, financial traders like Soros, who previously became famous by "breaking" the Bank of England, also speculated against the Swedish currency. After a spectacular rate hike to almost 500% to defend the currency, the Riksbank was forced to abandon the pegged exchange rate (Englund, 2015). The asset price bust also led to a domestic banking crisis, and financial institutions had to be supported and bailed out by the state. The depreciation of the Swedish currency then led to a swift recovery, partially based on exports, but also based on domestic spending as the period of tight money came to an end (Englund, 2015).

Thanks to the financial crisis in the early 1990s, Sweden was one of the very few countries that did not experience a financial crisis in 2008, as the domestic banking system turned out to be much more robust and also less exposed to junk bonds and other toxic assets during the international financial credit crunch that ensued in 2008. While the domestic financial sector turned out to be resilient, being a small open economy at Europe's periphery, Sweden was unable to decouple itself from global macroeconomic trends. Interest rates reached the ELB and have stayed there for since 2014. Economic growth has been timid in the aftermath of the crisis. It is still relatively early to say whether this was simply a result of global delever combined with a strong demand-side slump (Rogoff, 2016), especially in Europe, or whether there are also structural factors at work (Clark, 2016). Productivity growth certainly has been abysmal in most advanced economies since the early 2000s, including Sweden, and it increasingly starts to look like a trend instead of just a temporary blip, which would be in accordance with Robert Gordon's (2017) theory of technological pessimism.

The US economy from the postwar period to today

The US economy has experienced several distinct economic phases since the end of World War II. According to Maddison (2004), the cycle theory proposed by some Austrian economists is not very constructive, and from an analytical point of view, it makes more sense to speak of different economic phases. While the long-run economic trend of US per capita growth has been hovering around 2% for more than a century, there are certainly several decennial shifts when growth has either been higher of slower than the long-run average (see table 1 below). The immediate postwar period was, in contrast to Alvin Hansen's suggestion of secular stagnation (Hansen, 1939), characterized by extremely high population growth. The upbringing of the baby boomer generation combined with rapid technological progress had the obvious consequence of pushing up labor productivity, thus creating the seeds for the postwar economic boom. According to Gordon (2017), some key general purpose technologies led to extremely rapid growth in the postwar period. The construction of the interstate highway system along with the development of the automobile industry played a particular role in the economic development process, which also allowed for the rise of the suburbs in postwar America (Gordon, 2017).

Table 1:
Average GDP growth US economy, selected periods

Period	Growth Rate	Period	Growth Rate
1870–2007	2.03	1973–1995	1.82
1870–1929	1.76	1995–2007	2.13
1929–2007	2.23		
1900–1950	2.06	1995–2001	2.55
1950–2007	2.16	2001–2007	1.72
1950–1973	2.50		
1973–2007	1.93		

Source: Jones (2016)

Three decades of relatively high and uninterrupted growth came to an end in the early 1970s when several global macroeconomic factors ultimately culminated in the end of the Bretton Woods system. The finance efforts of the Vietnam War combined with expansionary monetary policy led to high domestic inflation rates. The global oil price shocks led to the stagflation outcome, a period of low productivity growth and high inflation rates that were approaching about 10% by the end of the 1970s (Eichengreen, 1998). Under Fed chair Paul Volcker, the Fed created a recession in the early 1980s, thus bringing down inflation expectations with restrictive monetary policy as real interest rates spiked and the dollar appreciated sharply (Romer, 2016). By the end of the 1980s, inflation rates were down significantly and the Fed informally started to target an inflation rate of about 2% under the tenure of Alan Greenspan (Bernanke, 1999).

The internet boom and the Dot-Com bubble of the 1990s led to a significant economic expansion with extremely low unemployment rates and high productivity growth that lasted for about a decade (Oulton, 2012). In the early 2000s, the Dot-Com bubble burst and was subsequently replaced with the housing bubble. Global interest rates were already on a significant downward trend (Rachel and Smith, 2015), including the US. The Fed's benchmark interest rate stayed extremely low for several years in the run-up of the Global Financial Crisis because excess savings in South-East Asia depressed interest rates on a global level (Bernanke, 2005). While the financial crisis of 2008 primarily originated in the US, and more specifically in the subprime market for American mortgages, there is no doubt that there were global forces at work. Obstfeld and Rogoff (2009) have identified global imbalances, excessive capital flows and current account imbalances, as one of the proximate causes for the financial crisis. Furthermore, a number of studies have now shown that monetary policy was extremely tight in the US and elsewhere in 2008 when the financial crisis started to turn into a serious economic downturn (Sumner, 2011).

While the US economy was hit by the worst negative macroeconomic shock since the Great Depression with the unemployment rate spiking at 10% in 2010, the following years were one of timid economic recovery (Krugman, 2012). As of 2018, unemployment rates are again below 4% and the economy is booming. However, productivity growth has been abysmal worldwide over the last 10 years despite all the technological hype coming out of Silicon Valley. It is still unclear whether the current slowdown will persist and whether Gordon's (2017) technological pessimism is warranted, or whether we will eventually escape the current cycle and shift gears again towards a higher productivity environment (Clark, 2016).

Global monetary regimes from 1870 to today

Two of the papers of the thesis use long-run macroeconomic history data for 17 advanced economies from about 1870 to 2013. The global economy and monetary system underwent several macroeconomic regime changes over the last 150 years. In the early 1870s, all major economies were on some kind of commodity standard. While some countries like China had their currency pegged to the price of silver, most of the advanced economies in the sample had joined the classical gold standard in the 1870s, meaning that all currencies were fixed to the price of gold and thus also with respect to each other (Eichengreen, 1997). Some of the Central Banks like the Swedish Riksbank or the Bank of England have existed since the late 16th century, first as commercial banks and then as public entities. Most other countries like the US, however, did not have a Central Bank during that time period. The Federal Reserve, for example, was only founded with the Federal Reserve Act of 1913 in the aftermath of a financial crisis that revealed that the US monetary system lacked a lender of last resort (Meltzer and Goodhart, 2005).

While the classical gold standard restricted Central Banks to some extent to pursue discretionary monetary policy, it has been argued that the price-specie flow mechanism suggested originally by Hume (2015), was not exactly how the gold standard worked in practice, thus leading to the famous Gibson's paradox (Barsky and Summers, 1988). Hume's original argument rested on the quantity theory of money (Glasner, 1989). Countries with a positive trade balance would experience gold inflows and see their prices rise, thus leading to balanced trade. Conversely, countries with a negative trade balance would experience gold outflows, which would lead to a fall in prices and balanced trade. The adjustment mechanism was thus supposed to be gold flows between countries (Hume, 2015). However, a number of empirical studies have shown that the aforementioned adjustment mechanism did not really apply (Eichengreen, 1997; McCloskey and Zecher, 2013). Instead, under the gold standard, domestic price levels were set by the international demand and supply for gold. International goods arbitrage between traded goods would therefore determine the domestic price level (McCloskey and Zecher, 2013). The quantity of credit and bank money was strictly speaking not a function of domestic gold reserves either, but rather endogenously determined within the macroeconomy. As the international price level was determined in the global market for gold, any major shocks in the gold market would have repercussions for national inflation rates. The gold discoveries in the Australia and California in the late 19th century, for example, produced a significant increase in the inflation rate on the global level for the countries that had their currencies pegged to gold (Eichengreen, 1997).

The classical gold standard was also a time of high factor mobility on the global level. The late 19th and early 20th century corresponded to the first period of hyperglobalization as both trade flows and capital flows between countries took off (Bordo and Meissner, 2007). Furthermore, labor was relatively mobile as well with millions of people emigrating from the poorer parts of Europe to the Americas, and also to a lesser extent the other settler colonies like Argentine, South Africa, and Oceania (Hatton and Williamson, 2005).

As a result of World War I, some countries abandoned the gold standard in order to finance their war efforts by monetary finance, i.e. printing money. While in the aftermath of the war, the countries decided to join the gold standard again, France did so at an undervalued exchange rate whereas the UK decided to peg the Pound Sterling to gold at the pre-war parity, meaning that her currency was highly overvalued. The resulting disequilibrium led to a period of economic stagnation and high unemployment for several years in the UK economy as a result of the misaligned exchange rate (Keynes, 1930).

While former studies have blamed the Great Depression mostly on the popping stock market bubble in the US (Temin, 1976) and the actions taken (and not taken) by the Federal Reserve (Friedman and Schwartz, 2008), a lot of recent research now supports the notion that the Great Depression was the result of international forces (Batchelder and Glasner, 1991). It is especially two major Central Banks, the Federal Reserve but even more so the Banque de France, which are to blame since they started to accumulated an enormous amount of the international gold reserves in the late 1920s (Irwin, 2010). As previously predicted by Ralph Hawtrey and the Swedish economist Gustav Cassel, the gold standard would eventually impose deflationary tendencies on the global monetary system if international gold supply could not keep with gold demand. While on the supply side the mining of gold would most likely would have turned out to be sufficient to keep up with demand, the insane accumulation of gold reserves by those two major Central Banks drained a huge amount of gold reserves from the system, thereby imposing deflationary tendencies on the global level. The increase in the price of gold implied that the price of all other goods must fall in equilibrium (Irwin, 2010). While Hawtrey and Cassel correctly anticipated the deflationary tendencies that were baked into the gold standard, both the Federal Reserve and the Banque de France failed to understand the repercussions of their policies (Batchelder and Glasner, 2013). The deflation that was imposed on the global level was exacerbated by domestic policy failures, such as the Fed's desire to lean against the wind and pop the domestic stock market bubble. Deflating asset prices combined with deflationary tendencies then led to a severe recession (Batchelder and Glasner, 1991), which ultimately turned into the Great Depression once banking panics and banking failures occurred countrywide, thus causing a further contraction in the domestic money supply (Friedman and Schwartz, 2008). Eastern and Central Europe experienced something akin to a sudden stop as the ample supply of international credit before the crisis, mostly originating from the US, was withdrawn rather abruptly. Banking failures and market panics spread from Austria to Germany, leading to severe economic contractions in Europe as well (Eichengreen, 1998).

A lot of research has shown that the countries that left the gold standard the earliest were also the countries to recover the fastest from the Great Depression. The currency devaluation and the associated monetary expansion in the countries that left the peg to gold allowed them to pull out of the economic downturn. The Scandinavian countries were among those that devalued early and also did not suffer from the Great Depression to such an extent like France, for example, which stayed on the gold standard until the very end when the entire system collapsed, as countries abandoned the peg to gold one by one (Eichengreen and Sachs, 1986).

The postwar global monetary system was designed at the conference of Bretton Woods where it was agreed upon that all major currencies would be pegged to the dollar, which itself was convertible at a fixed exchange rate into gold. Unfortunately, the system suffered from a fatal design flaw. Since countries depended on using the US dollar as the international reserve, many European nations were forced to run current account surpluses in order to accumulate US dollars (Eichengreen, 1998). The US, on the other hand, had to run persistent current account deficits in order to provide the world with the necessary dollar reserves. This is also known as the Triffin dilemma, since Triffin was one of the first to elaborate on how this system would eventually break down (Eichengreen, 1998).

As a result of the Vietnam War efforts, federal spending in the US went out of hands. As the fiscal deficit increased in size, the convertibility of the dollar into gold at the promised fixed rate was called into question.

Ultimately, the system might have survived if no one had questioned the dollar's convertibility into gold. However, as the French government decided to convert its dollar reserves into gold in 1973, the US reneged on its promise and abandoned the convertibility, meaning that the system broke down (Eichengreen, 1998). As the fixed exchange rate arrangement of Bretton Woods was abandoned, currencies were allowed to float against each other. The first decade after Bretton Woods was characterized by high inflation rates since advanced economies were subject to the oil shock, while at the same time pursuing expansionary policies by pushing down unemployment rates below the natural level, thus creating a wage-price spiral. Once inflation rates approached 10% in the US and in other advanced economies, Central Banks started to push aggressively against this trend as to not let things spiral further out of control. Paul Volcker therefore hiked real interest rates by several percentage points and created a recession, which pushed down inflation (Romer, 2016).

Starting in the early 1990s, Central Banks adopted a new doctrine, the 2% inflation target, which is defined as price stability, and that most advanced economies have successfully adopted since (Bernanke et al., 1999; Jonung and Fregert, 2008). The recent period of free exchange rates and high capital mobility has led to an era of unprecedented financial globalization and global trade flows, a second wave of hyperglobalization about a century after the first one had started. While some emerging market economies did suffer from financial and macroeconomic instability, such as the Latin American debt crisis, the South-East Asia crisis, the Russian financial crisis (Krugman, 2000), global economic growth actually accelerated. Advanced economies experienced several decades of macroeconomic stability, known as the Great Moderation (Bernanke, 2004), which ultimately culminated in the Global Financial Crisis of 2008 and the Great Recession that ensued thereafter. However, during the Great Moderation, some worrying macroeconomic trends already started to appear that would turn out to be problematic as soon as the party ended in 2008. In hindsight, advanced economies have experienced a significant increase in leverage and several debt-driven asset price bubbles in recent decades, so-called Minsky cycles (Dalio, 2012), which turned out to be the precursor to the Global Financial Crisis (Jorda et al., 2011; Jorda et al., 2013).

Methods

The main goal of this thesis is to test important macroeconomic mechanisms within the field of economic growth, economic distribution, and the determination of factor shares and factor prices. We have chosen to use a variety of different methodologies that are mostly quantitative in nature. We will not discuss in greater detail the pros and cons of qualitative research vs. numerical research, but leave this discussion to others (Neuman, 2013). Suffice it so say that economic history can contribute to the social sciences in general, and to the field of economics in particular, by testing economic hypotheses using historical data. The historical analysis is, of course, not only interesting in its own right, but it also allows us to expand the number of observations in our dataset. This thesis, as a study of economic mechanisms throughout history, is based on different quantitative models to test the hypotheses and research questions outlined in the previous section. We use various statistical tools and regression techniques that are summarized in the following section.

Panel models

1) Panel-OLS

One of the large problems of empirical macroeconomic research is the limited amount of data that is available, especially when one uses annual data like we do in our papers. Instead of focusing on individual countries, we use panel data regressions to increase the number of observations in our analysis. The advantage of this approach is to increase the efficiency and robustness of our estimations. The obvious disadvantage is that using this method we cannot uncover country-specific factors and shocks. We therefore disregard cross-country differences in our estimation by design. Moreover, the model also imposes that every country has equal weight, as we estimate an average marginal effect. These restrictions can be defended on the grounds that a panel approach can help us uncover systematic macroeconomic relationships that might otherwise be hidden if we were to estimate each regression separately for each country in the panel (Gavin and Theodorou, 2005).

In the second paper of the thesis, we estimate a regular Panel-OLS (Ordinary Least Squares) model to detect a statistical relationship between the capital share and asset prices. The advantage of the Panel-OLS structure is that it allows us to also include time fixed effects as to control for unobserved yearly macroeconomic shocks. On the other hand, one must be aware that including time dummies comes at the cost of reducing the power of our estimation, since in our case the time dimension is very large while the panel structure only includes 17 advanced economies. We also include a time trend that we interact with country-dummies in order to control for country-specific long-run secular trends in our data. The obvious disadvantage of the Panel-OLS model is that it does not help us to directly establish causality, but simply mere correlations. We therefore need to use alternative specifications if we want to tease out causal relationships between macroeconomic variables.

2) Panel-VAR

The literature on the macroeconomic business cycle and the propagation of economic shocks is relatively old and dates back to the beginning of the 20th century (Ramey, 2016). Indeed, Wicksell (1907) seems to be the first one who used the rocking horse example as an analogy how economic shocks propagate throughout a dynamic system, therefore creating the business cycle. The analysis of Frisch (1933) revolutionized the study of economic fluctuations. In his research, he outlined how random shocks can propagate through the economic system to create boom and busts (Frisch, 1933). The focus thus shifted from the Schumpeterian analysis towards the more modern view of the causes of the business cycle. While the former has outlined an endogenous view where the boom is creating and causing the subsequent bust (Schumpeter, 1961), most modern scholars have accepted the more classical view in which random shocks to the macroeconomic system are the origin of economic fluctuations (Ramey, 2016).

During the early 1980s, macroeconomic analysis was revolutionized in several ways. First, Sims (1980) introduced vector autoregression models (VARs), which made it easier for researchers to identify shocks to a linear system and estimate impulse response functions. Shocks in such a system are equivalent to structural disturbances in a simultaneous equation system (Ramey, 2016). According to Bernanke (1986) and others (Stock and Watson, 2016), shocks should be primitive exogenous forces, but they should also be economically meaningful. Ramey (2016) thus identifies three key characteristics for a macroeconomic shock to be plausible and meaningful. First, the shock must be exogenous to other current and lagged endogenous variables. Second, it should be uncorrelated with other exogenous shocks. And third, it should represent either unanticipated movements in exogenous variables or news about future movements in exogenous variables (Ramey, 2016).

While VAR models have become standard practice on the macroeconomic research agenda, there are some obvious problems with this kind of methodology as well. First, given that the VAR model is based on a system of endogenous variables, one cannot include a large number of variables or else the system will eventually blow up and the power of the estimation will be reduced significantly. The obvious advantage of the VAR methodology, on the other hand, is that it allows us to estimate a set of impulse response functions (IRFs). The estimated IRFs capture the effect of an innovation or shock to one of the variables on the other endogenous variables of interest (Ramey, 2016). In that sense, VAR models are superior to other empirical strategies, meaning regular regression techniques, since they allow us to establish causality, given that the original model is not misspecified (Ramey, 2016). We can therefore more easily speak of causal impacts instead of finding mere correlations.

In the second paper of the thesis, we estimate a Panel-VAR model to establish causality between rising asset prices and the capital share of GDP. Panel-VAR models take the panel structure of our macroeconomic data into account. As outlined above, the advantage of this methodology is to increase the number of observations, which is always a problem with historical macroeconomic data. While it therefore also increases the power and efficiency of the estimator, the disadvantage is that we only estimate the average marginal effect across our panel and that cross-country heterogeneity is hidden by assumption. On the other hand, as argued by Gavin and Theodorou (2005), this approach can help us uncover systematic macroeconomic relationships that might be hidden by idiosyncratic factors on the country level if we were to estimate the model for each country separately.

Factor methodology

Factor methodologies were originally applied in social sciences outside the domain of economics and macroeconomics. Static factor analysis relies on extracting one or several common variables from a large set of underlying correlated variables, therefore reducing the amount of information to a smaller number of latent variables, also called factors (Bartholomew et al., 2008). Factor analysis was originally applied to panel data sets, thus making it somewhat useless in the realms of macroeconomics where most data structures have a time series dimension as well (Stock and Watson, 2016). Moreover, as we all know, time series data tends to be prone to autocorrelations and unit roots, which can lead to spurious regressions and other problems that render regular statistical regression techniques unreliable. Therefore, different statistical tools, such as cointegration for example, are required to deal with these problems (Engle and Granger, 1987; Enders, 2008). More recently, factor analysis has found itself being applied to macroeconomic data as well. More specifically, dynamic factor analysis has been used to extract real-time GDP estimates from a large number of underlying macroeconomic variables. Both the Atlanta Fed and the New York Fed GDP Nowcast models are based on the dynamic factor methodology (Giannone et al., 2008). Macroeconomists have explicitly introduced the time dimension into factor analysis, thus making it dynamic, in order to deal with the aforementioned issues that time series data usually introduces. Therefore, dynamic factor analysis takes the structure of time series data into account and usually explicitly models the underlying factor variable(s) in terms of some standard autocorrelation function (Stock and Watson, 2016). The disadvantage of dynamic factor analysis, on the other hand, is that the underlying structure of the dynamic factor is usually assumed by the researcher ex-ante. This seems to be an unnecessary restriction, especially if one is somewhat uncertain about the dynamic behaviors of the underlying factor(s), as outlined by Gilbert and Meijer (2005).

We have chosen to follow the approach suggested by Gilbert and Meijers (2005) who have introduced time series factor analysis (TSFA) as a viable alternative to dynamic factor analysis. Their approach is more in line with exploratory factor analysis because it does not impose any kind of restrictions on the dynamics of the underlying factor(s) beforehand, but instead allows the data to speak more freely (Gilbert and Meijers, 2005). Furthermore, their model also has the desirable property for macroeconomic analysis to not impose that the underlying factor(s) has (have) zero mean. Finally, TSFA also takes the time series dimension into account and allows for serial correlation in the error term (Gilbert and Meijer, 2005).

Given that we are completely uncertain about the structure of the underlying factor(s), we have therefore chosen TSFA as the most appropriate methodology to extract two global factors from national real interest rate data for the time period from 1870 to 2013.

Median slope estimator

The first paper of the thesis estimates the rank-size rule for all Swedish cities from the early modern period to today. While older research papers have simply estimated the relationship with regular OLS (Krugman, 1996), some authors have noted that the OLS estimator suffers from a number of flaws (Gabaix, 1999b). More specifically, it is well known that OLS is quite sensitive to outliers (Dittmar, 2011). This is especially a problem in our case, given the time period we consider. A number of Swedish cities were still extremely small a couple hundred years ago and barely had a few hundred inhabitants. We therefore have a number of outliers in our sample at the bottom of the city size distribution. Consequently, we follow the advice of Dittmar (2011) and estimate the rank-size rule using the Theil-Sen median slope estimator (MSE). MSE is a method for robustly fitting a line through sample points in a plane by choosing the median of the slopes of all lines through pairs of points (Theil, 1992). The estimator can be computed efficiently and it has been shown that it is more insensitive to outliers. This non-parametric technique is therefore more accurate than non-robust simple linear regression for skewed and heteroscedastic data (Sen, 1968). Moreover, the Theil-Sen estimator also allows us to estimate the slope coefficient at different percentiles throughout the rank-size distribution (Dittmar, 2011).

Data for the thesis

This thesis uses long-run historical data to contribute to the growing literature on macroeconomic history. We have to admit that we have not gathered any data ourselves, but relied on the hard work of others instead. Regardless, we hope to make an important contribution to the field of macroeconomic history by using the data in novel ways. Our aim is to test some important macroeconomic theories using a variety of empirical research methods discussed above.

Table 2 summarizes the main data sources we have used for the four papers in the thesis. The first paper focuses on the capital share in the US during the postwar period. We mainly use data from the BEA as well as from the St. Louis Federal Reserve database FRED to get estimates for US GDP, imputed rents, and most importantly, depreciation rates, both by asset class and by sector, and several other macroeconomic variables of interest. We also include some international evidence on depreciation rates based on the data from Bengtsson-Waldenström and the OECD.

Table 2:
Data sources for the thesis

Database	Variables
BEA	Macroeconomic variables for the US, postwar period
FRED database	Macroeconomic variables for the US, postwar period
Macrohistory database (Jorda, Schularick, and Taylor; 2016a, 2016b)	Macroeconomic variables for 17 countries from 1870 to 2010: GDP growth, inflation, trade data, government spending, stock prices, house prices
Bengtsson- Waldenström capital share data (2015)	Gross capital share, net capital share, depreciation rates for my 17 countries from 1875 onwards
OECD	OECD capital share data after 1970
Folknet Database	Population data for all Swedish cities from 1810 to 1990, 10-year intervals
SCB	Population data for all Swedish cities for 2000 and 2010

Theory and literature review

In the following section of the thesis, we devote our attention to the theoretical foundations and the literature review concerning recent global macroeconomic trends. We will also discuss in great detail the determination of factor shares and real interest rates, mostly within the framework of neoclassical and neo-keynesian macroeconomics.

Literature review on factor shares

The literature on factor shares has grown exponentially, given the richness of historical data that has been gathered by economic historians in recent years. While many economic studies have restricted themselves to an analysis in the post Bretton Woods periods (Karabarbounis and Neiman, 2014), some economic historians have gathered data and analyzed factor shares in the very long-run, using data from the late 19th century to today (Bengtsson, 2012; Bengtsson and Waldenstöm, 2018; Piketty, 2014).

Many economists have restricted their attention on the declining wage share in recent decades, both across advanced economies and for emerging markets (Karabarbounis and Neiman, 2013; Karababarbounis and Neiman, 2014). Several key explanations have been put forward to explain this particular trend. Some authors have emphasized financialization and globalization as the culprit (Stockhammer, 2013), as both factors would tend to decrease the bargaining power of labor, given that firms can more easily locate in low-wage economies (Guscina, 2006). Other authors have focused on increasing markups (Barkai, 2016) and the rise of superstar firms, which tend to be more capital-intensive (Autor et al., 2017; Dorn et al., 2017). Finally, the erosion of labor unions and organized labor in general also seems to have a depressing effect on wages and the labor share (Fichtenbaum, 2011).

A separate strand of research has emphasized the recent secular increase in asset prices and private sector leverage in recent decades (Jorda et al., 2015b). While inflation-adjusted house prices have stayed relatively constant for almost a century from about 1870 to 1970, the end of the Bretton Woods period initiated a period of rapid financialization and globalization of international capital flows. Real house prices have roughly tripled since the 1970s across a sample of advanced economies. This increase has come hand in hand with spectacular increases in the private sector debt to GDP ratio.

Moreover, most of the increase in debt is directly linked to housing mortgages, which make up a substantial fraction of private sector liabilities (Turner, 2015). Some authors have therefore argued that inflated asset prices, and especially real estate, have pushed down the labor share (Cho et al., 2017).

Economic historians, on the other hand, have recently examined factor shares over very long time periods using more than a century of data, spanning back to the late 19th century and prior (Piketty, 2014). These investigations have mostly revealed that the constancy of factor shares was always a somewhat dubious assumptions, given that the capital share has fluctuated wildly over the last century, assuming relatively high values both in the beginning and at the end of the 20th century in most advanced economies (Bengtsson and Waldenström, 2015).

The historical analysis seems to be a more fruitful in the sense that it also reveals the evolution of factor shares in the very long-run. Piketty (2014) and others have shown that it is the postwar period with extremely high labor shares that was the anomaly rather than the norm. In fact, labor shares were also much lower in the late 19th and early 20th century during the first wave of hyperglobalization. Three major shocks, the two World Wars and the Great Depression led to an enormous amount of capital destruction on the global level, therefore depressing the capital share of GDP for decades to come (Piketty, 2014). The long-run analysis thus shows that in most advanced economies the capital share displays a U-shaped pattern over the course of the 20th century (Bengtsson and Waldenstöm, 2018). Furthermore, while capital shares have risen substantially in recent decades, they now seem to approach again a value consistent with what they have had historically in the beginning of the century (Piketty, 2014). The recent decline in the labor share is thus not the freak event that some economists make it out to be by restricting their analysis to the last few decades alone.

Factor shares: The short-run

There is no doubt that short-run elasticities and long-run elasticities differ from each other, given that the substitutability of factor inputs depends on the relevant time horizon: Long-run elasticities are therefore usually larger than short-run elasticities, given that firms have better opportunities to switch methods of production in the medium to long-run (Jones, 2005).

Business cycle analysis has mostly revealed that labor share fluctuations do not move in a consistent and predictable manner with output movements (Schneider, 2011). While some basic neo-keynesian models postulate that markups move pro-cyclically (Nekarda and Ramey, 2013), thus generating a counter-cyclical fluctuation in the labor share (Hansen and Prescott, 2005; Choi and Rios-Rull, 2009), one can easily introduce some friction in the model, which leads to the opposite result (Schneider, 2011). Cantore et al. (2018), for example, assert that the labor share moves pro-cyclically over the course of the business cycle. However, the data seems to be at odds with the theory. Their findings also imply that a monetary tightening leads to an increase in the labor share during the Great Moderation across a set of advanced economies. As such, to what extent labor shares move together with the business cycle is thus ultimately a matter of empirics, given that neo-keynesian models can generate different results (Schneider, 2011).

Factor shares: The long-run

Most neoclassical growth theory assumes relatively easy production function. The aforementioned Solow model, for example, relies on the Cobb-Douglas production function where the factor shares are simply equal to the share parameters α and $1-\alpha$, respectively. It is then simply assumed that the capital share is roughly equal to one third whereas the labor share is about two thirds of total output (Solow, 1956).

More recently, some growth models have suggested a CES production function, with the special case of an elasticity of substitution between capital and labor of one yielding the Cobb-Douglas production function. Arrow et al. (1961), for example, derive the labor share for the case of the CES production function and find the following result for the labor share:

$$(1) \qquad LS = (1-a)^{\gamma} * (\frac{w}{B})^{1-\gamma}$$

An increase in the capital labor ratio does not have any effect in the Cobb-Douglas production function because of offsetting changes in relative input prices (changes in r and w) in such a way as to make factor shares always constant. Similarly, in the CES case, there are two countervailing effects: An increase in the capital-output ratio tends to increase the labor share if the elasticity of substitution is below unity whereas neutral technological change has an offsetting effect of depressing the labor share, meaning that even in the CES case one can find examples of a constant factor share in the long-run (Arrow et al., 1961; Schneider, 2011). The constancy of factor shares, one of the so-called Kaldor facts (Kaldor, 1961), is one of the central tenets of neoclassical growth theory and stems from the simplicity of some of the models. Within this framework, Jones (2016) and others (Ferguson, 1968) have suggested that factor shares tend to be mean-reverting and constant in the long-run, given that macroeconomic quantities in steady state are growing at the same exponential rate (Schneider, 2011). However, as argued above, economic history data does not seem to support this hypothesis

On real interest rates and global macroeconomic trends

Advanced economies have seen over the last decade a remarkable productivity slump combined with a prolonged period of both low nominal and real interest rates in the aftermath of the financial crisis of 2008. Some economists have explained the sub-par economic performance as being the result of the financial crisis itself (Rogoff, 2015). So-called hysteresis effects combined with the monetary policy constraint caused by the effective-lower bound on nominal interest rates have created a deep recession and might have also cast a shadow on future output (Blanchard and Summers, 1987). Regardless, most neo-keynesian models assume a return to the long-run equilibrium of full employment within a few years after being hit by an adverse economic shock. Consequently, many private and public entities have forecasted in recent years that "normalization" of interest rates as well as an increase in GDP growth would occur. Regardless, real interest rates have continued their long-term downward trend well after the financial crisis and GDP growth has remained sluggish (Summers, 2014). Fernald (2015) has documented that productivity growth already started to decline well before the financial crisis. Indeed, it is somewhat puzzling that with all the fears about automation in recent years productivity growth has been stalling. In fact, the UK experienced its worst decade in terms of productivity growth since 1820, the outset of the first Industrial Revolution (Lewis, 2018). While automation certainly seems to advance in industrial production, the sector has become a much smaller part of the economy in recent decades. With the service sector becoming ever more dominant, maybe advanced economies are now suffering from a version of Baumol's cost disease (Baumol, 2012).

Larry Summers (2014) has recently revived the hypothesis of secular stagnation, a theory first put forward by Alvin Hansen in the late 1930s. Hansen proposed that the US economy might face a period of slow growth once the war was over because the fiscal wartime spending would be withdrawn (Hansen, 1939). Of course, just the opposite happened. Productivity growth accelerated and the economy surged as a result of investments into key general purpose technologies (the automobile and the construction of the interstate highway system) and the baby boom (Gordon, 2017). While future productivity growth is notoriously difficult to predict, Summers' theory has come at a time when most advanced economies have experienced a decline in productivity from its surge in the 1990s thanks to the Dot-Com boom. Gordon (2017) has highlighted that the "golden age" of economic growth might come to an end as most of the low-hanging fruits have already been picked up. Future innovations in the realm of finance, the service industry, and even ICT technologies are unlikely to spurn a future productivity boost (Gordon, 2017). Moreover, financial markets have priced in many years of low interest rates and low inflation even in the decade ahead, a full 10 years after the outbreak of the financial crisis (Summers, 2015). In what follows, we discuss the relationship between real interest rates, real growth rates, population growth, and other key parameters of interest within the neoclassical framework.

Literature review on real interest rate

The following exposition relies closely the theoretical approach of Baker et al. (2005) who examine the future return to capital, and more explicitly the implied prospect for future US stock market growth, within the framework of neoclassical growth models. The authors find that in the absence of other structural shifts, the decline in productivity growth combined with a decline in the rate of population growth, implies a lower return of capital in the decades ahead. However, the article provides little empirical evidence to substantiate this result. More recently, Piketty (2014) has found that rates of return are relatively stable over time, regardless of the capital-output ratio, thus providing a certain blow to the neoclassical analysis. This result was backed up more recently by Jorda et al. (2017a) who have examined the rate of return on all asset classes, short-term and long-term bonds, stocks, and real estate, for a panel of 17 advanced economies from 1870 onwards. The authors find that the real return on stocks has been relatively stable across long time periods. On average, equity has yielded a real return of above 9% after 1950 in the panel of advanced economies. More remarkably, real returns on real estate have almost performed equally well. The real return on safe assets, on the other hand, has showed much more instability, meaning that the risk premium has varied widely over the time period under consideration, being very high in the decades after World War II and narrowing down post-1980 up to the Global Financial Crisis of 2008/09. Furthermore, the difference in returns between bills and bonds has also varied quite significantly over time (Jorda et al., 2017a).

More recently, several studies have attempted to answer the question on why we face a prolonged environment of low real interest rates, using the framework of secular stagnation as a point of reference. Andy Haldane (2015) reports that global interest rates are at their lowest level since Babylonian times. Similarly, Rachel and Smith (2015) have examined the causes of falling real interest rates within a more neoclassical framework and suggest that most of the global decline can be attributed to demographics, inequality, precautionary savings, and the falling price of investment goods. These forces have affected the equilibrium real interest rates by shifting the savings schedule to the right. Similarly, the falling price of capital goods has shifted the investment schedule to the left. Together, those factors can account for most of the decline in global real interest rates (Rachel and Smith, 2015). Lu and Teulings (2017) explain that the decline in fertility across advanced economies produces cohort effects that can lead to an inverted age pyramid, such as in Japan or Germany. As the working population has to save for retirement, this will put downward pressure on the real interest rate because the large supply of savings cannot be absorbed by the young, whose cohorts are smaller in size (Lu and Teulings, 2017). The authors produce an overlapping generations model (OLG) that can produce negative real interest rates for a prolonged time period, a result that is inconsistent with most neoclassical growth models, but certainly is in line with empirical findings, which have shown that real interest rates can remain negative for prolonged time periods. This result is also consistent with the model by Eggertson et al. (2017) who show that a secular stagnation outcome with negative equilibrium real interest rates can be produced within an OLG framework.

More recently, Lunsford (2017) has estimated the long-run relationship between productivity growth and real interest rates for the US and has found no statistically significant correlation for the two variables, a finding that is seemingly at odds with macroeconomic theory. Similarly, Bosworth (2014) uses panel data for the G7 countries to study the determinants of real interest rates for the period after 1970. He also finds that real growth rates and real interest rates are not statistically significantly correlated. On the other hand, international factors like capital inflows and the global real interest rate, seem to play a much stronger role in the determination of domestic interest rates over the last few decades, a result that is not very surprising given the high degree of capital mobility in today's global financial markets.

Real interest rates and output growth: The short-run

Most modern macroeconomic models suggest a positive relationship between real interest rates and output growth in the short-run. In the standard real business cycle (RBC) model of the closed economy, for example, real interest rates are positively correlated with output (Rebelo, 1999). The RBC model posits that output fluctuations are largely driven by technology shocks. The real interest rate is determined by structural factors and pinned down by the marginal product of capital. A positive productivity shock with a sufficient degree of persistence means that output jumps to a higher level and gradually returns to its steady state. Accordingly, the real interest rate jumps as well as the marginal product of capital increases and then starts to decrease gradually, thus leading to the positive correlation between output and interest rates (Sørensen and Whitta-Jacobsen, 2005). The neo-keynesian literature has for the most part adopted the core components of the RBC model. Modern DSGE models posit that consumers optimize their consumption behavior according to the so-called Euler equation (Korinek, 2017). The real interest rate is pinned down by the marginal rate of substitution between future and current consumption. As a positive income shock increases future consumption (and thus decreases the marginal utility of future consumption), the real interest rate must rise as to equate the marginal rate of substitution with the price ratio, thus leading again to a positive relationship between real interest rates and output growth (Beaudry and Guay, 1996):

$$(2) \quad MRS = \frac{MU\,(C_{current})}{MU(C_{future})*\beta} = 1 + r$$

Microeconomic evidence suggests that consumers actually do not act in line with the predictions of the standard Euler equation, which in turn led to the adjustment of the baseline model (Begum, 1998). As such, the introduction of a habit formation parameter in the consumption optimization problem, for example, and the introduction of capital adjustment costs in the capital formation process can induce a negative correlation between real interest and output growth in the model, which might be more in line with empirical result (Beaudry and Guay, 1996; Begum, 1998).

The standard Keynesian aggregate supply-aggregate demand (AS/AD) model also took on board the Friedmanite assumption that the natural rate of interest r* is solely determined by structural factors in the long-run (Friedman, 1995). The natural rate is the interest rate that brings about a balance in aggregate demand and aggregate supply. While Central Banks have a short-run impact on the real interest rate in the neo-keynesian model via the rate of inflation, they have no influence over the natural rate that is determined by the economy's long-run structural equilibrium (Sørensen and Whitta-Jacobsen, 2005). In the standard AS-AD framework, the correlation between output and the real interest rate depends on the nature of the shock. A positive supply shock increases the economy's long-run potential output, which in turn requires an increase in aggregate demand. To maintain equilibrium in the goods market, the natural interest rate must thus go down, a prediction which is at odds with the core RBC model. A permanent increase in aggregate demand, on the other hand, requires an increase in the natural rate of interest as long as potential output remains unaffected. The positive demand shock requires an increase in the natural rate in order to reduce the interest-rate sensitive components of aggregate demand, as to keep the goods market in equilibrium so that total demand does not exceed the long-run equilibrium level of output (Sørensen and Whitta-Jacobsen, 2005). Given Central Bank's tendency to behave in accordance with the so-called Taylor rule where the Central Bank responds to deviations from its inflation target as well as deviations from the natural rate of output, one can derive within the neo-keynesian framework the following relationship between interest rates and some key macroeconomic variables:

$$(3) \qquad r = r^* + h(\pi - \pi^*) + b(y - y^*) + \varepsilon$$

The Central Bank adjusts the ex-ante real interest rate r in the short-run via its control over the nominal interest rate, which it raises in response to inflation overshoots ($\pi > \pi^*$) as well as in the case when output is above its natural rate ($y > y^*$). Accordingly, this model predicts a positive relationship between output growth above trend and the short-run real interest rates. The natural rate of interest r*, on the other hand, is determined by structural factors alone and only responds to permanent shocks to aggregate supply or aggregate demand (Sørensen and Whitta-Jacobsen, 2005). To sum up, both the core RBC model and the more standard Keynesian model predict a positive correlation between output growth and real interest rates over the business cycle.

Real interest rates and output growth: The long-run

Most long-run neoclassical growth models completely omit from business cycle fluctuations. Moreover, money, credit, and in fact any nominal aggregates are also left out of the equation, literally. The Solow-Swan model is the standard benchmark model for any analysis of long-run economic growth. Output is produced using a Cobb-Douglas production function with three inputs, technology B, capital K, and labor L (Solow, 1956). The parameters of the production function correspond to the capital share α and the labor share $(1 - \alpha)$, which are commonly pegged at one third and two thirds, respectively:

(4) $$Y = B * K^{\alpha} * L^{1-\alpha}$$

Factor prices are determined in this model by the competitive market outcome where the wage rate is equal to the marginal product of labor $w = MPL = \frac{dY}{dL}$ and the real interest rate is equal to the marginal prodcut of capital $r = MPK = \frac{dY}{dK}$. Given the Cobb-Douglas production function, the real interest rate is simply equal to:

(5) $$r = \alpha(\frac{K}{Y})^{-1}$$

The real interest rate is thus a declining function of the capital-output ratio. The steady state of the model is achieved when the capital per effective worker ratio $k = \frac{K}{BL}$ reaches its long-run value, the capital output ratio is stable, and the process of capital deepening has stopped. More specifically, capital per effective worker (k) reaches its steady state value according to the law of motion:

(6) $$\Delta k = s * y - (n + g + d)k$$

where s is the savings rate, y is output per effective worker, n is the population growth rate, g is the rate of technological change, and d is the depreciation rate of capital. The parameters n, g, and d are all assumed to be exogenous in the model (Sørensen and Whitta-Jacobsen, 2005). Along the steady state growth path of the economy, the capital-output ratio of the economy thus assumes the following value in the long-run:

(7) $$\frac{K}{Y} = \frac{s}{n+g+d}$$

Plugging this last equation into the expression for the marginal product of capital, we obtain the following equation for the long-run real interest rate:

(8) $$r = \alpha * \frac{n+g+d}{s}$$

In the long-run, the marginal product of capital in the Solow-Swan model is thus determined by the following structural parameters: the population growth rate, the rate of technological change, the depreciation rate, the savings rate, and the capital share of GDP. Population growth, the rate of technological change, and the depreciation rate all increase the replacement demand for capital structures, thus leading to a positive correlation with the real interest rate (Aghion and Howitt, 2008). The savings rate determines the supply of capital and is thus negatively correlated with the price of capital. Within the Cobb-Douglas framework, the parameter α corresponds to the elasticity of output with respect to capital. A higher elasticity increases the marginal productivity of capital and thus implies a higher real interest rate (Sørensen and Whitta-Jacobsen, 2005). The Solow-Swan model also gives us a prediction for the natural rate of interest r*, which is simply the rental rate of capital r minus the depreciation rate:

(9) $$r^* = \alpha * \frac{n+g+d}{s} - d$$

At historical values for the US economy, the capital share is commonly assumed to be about 0.3, population growth of about 1%, the rate of technological change at 2%, the depreciation rate of about 4%, and a gross savings rate of about 22% of GDP. This implies a natural rate of interest (r*) of about 5.5% while the real rental rate of capital (r) should be close to 10%, according to the model, with the rate of depreciation commonly assumed to be about 4%. However, we will see that these predictions are commonly at odds with empirical results, which suggest a much lower equilibrium value for the natural rate of interest (Sørensen and Whitta-Jacobsen, 2005).

One should also be aware that the aforementioned parameter values are all steady state results and that the model converges to its long-run capital-output ratio at an extremely slow pace. More specifically, the steady state value is reached at the exponential rate of $-(1-\alpha)*(n+g+d)$. This implies that convergence is achieved at an annual rate of about 5.3%, which closes half the gap in about 14 years, and about 90% of the gap in about 45 years only (Baker et al., 2005). Furthermore, the speed of convergence predicted by the Solow-Swan model also seems to be at odds with empirical estimates that have found a much slower convergence to steady state (Mankiw et al., 1992). This is usually taken as an indicator that the Solow-Swan model is incomplete. Consequently, several extensions to the model have been made. More specifically, the Cobb-Douglas production function can be extended to include more factors of production. The two biggest sins of omission seem to be the exclusion of human capital, the exclusion of land, and the exclusion of energy as factors of production. Especially, the inclusion of human capital provides a much better fit to the model, since it reduces the speed of convergence by a factor of about one half to roughly two to three percent, which is much more in line with empirical estimates (Mankiw et al., 1992). The inclusion of human capital also provides more realistic estimates for the output elasticities with respect to the factor inputs. The expression for the long-run real interest rate in the steady state, on the other hand, remains virtually unchanged since the factor n*g is close to zero:

$$(10) \quad r = \alpha * \frac{n+g+d+n*g}{s}$$

Some economists have argued that the Cobb-Douglas production function is very specific because it corresponds to the case where the elasticity of substitution between capital and labor is exactly equal to one (Klump et al., 2012). In the more general case, output can be produced according to a constant elasticity of substitution (CES) function, which takes the following form:

$$(11) \quad Y = (a*K^{\frac{\gamma-1}{\gamma}} + (1-a)*L^{\frac{\gamma-1}{\gamma}})^{\frac{\gamma}{\gamma-1}}$$

with a representing the share parameter. In this more general case, the elasticity of substitution between capital and labor also plays a role in determining the capital share of output α as well as the real interest rate. More specifically, the capital share is equal to:

$$(12) \quad \alpha = \frac{r*K}{Y} = a*(\frac{K}{Y})^{1-\frac{1}{\gamma}}$$

We thus get the somewhat counterintuitive result that the capital share of GDP is a decreasing function of the capital-output ratio in the case where the elasticity of substitution between capital and labor is small, i.e. $\gamma < 1$. The reason is that when capital and labor are not very substitutable in the production function, the marginal product of capital falls steeply as the capital-output ratio rises. This causes a more than disproportionate decrease in the real interest rate so that (r*K)/Y actually decreases, The expression for the real interest rate r in the case of the CES production function is:

$$(13) \quad r = a*(\frac{K}{Y})^{\frac{-1}{\gamma}} = a*(\frac{n+g+d}{s})^{\gamma}$$

Similar to the Cobb-Douglas case, the real interest rate is always a declining function of the capital-output ratio. However, it now also depends on the substitution parameter γ. If capital and labor are highly substitutable in the production function, i.e. if $\gamma > 1$, then an increase in the capital-output ratio only induces a small decrease in the real interest rate (Piketty, 2014).

Neoclassical growth theory based on the Solow-Swan model first described the dynamics in the economy by simply modeling the behavior of economic aggregates without explicitly focusing on the microeconomic behavior of economic agents, such as consumers and firms, and the incentives they face (Aghion and Howitt, 2008). Microfoundations were later added to growth theory in order to address the Lucas critique (Lucas, 1972), according to which economic models are only consistent if they explicitly include the microeconomic optimization problem of all economic participants. The Solow-Swan model, for example, contains an exogenous and therefore constant savings rate, which seems to be a priori a poor approximation of economic realities. The Cass-Koopmans-Ramsey model belongs to the first class of models that contains an endogenous savings rate, which is based on the idea that households respond to macroeconomic conditions and optimize their consumption and savings behavior over time according to the constraints and economic environment they face (Aghion and Howitt, 2008). The continuous-time approximation of the consumption Euler equation with a general utility function corresponds to the following expression:

$$(14) \quad \Delta C_t * \frac{U''(C_t)}{U'(C_t)} = \rho - r$$

with ρ corresponding to the rate of time preference, which is strictly positive and a function of the discount factor (Aghion and Howitt, 2008). More specifically, $\beta = 1/(1+\rho)$. In the case of the isoelastic utility function, consumers have a constant rate of relative risk aversion:

$$(15) \quad u(C) = \frac{C^{1-\varepsilon}-1}{1-\varepsilon}$$

with $\varepsilon > 0$. The preceding Euler equation then becomes:

$$(16) \quad -\varepsilon * \frac{\Delta C_t}{C_t} = \rho - r$$

If consumption is growing at the rate of g, we can express the real interest rate as follows:

$$(17) \quad r = \rho + \varepsilon * g$$

The real interest rate is in thus a function of the rate of time preference ρ, the elasticity of substitution between current and future consumption $1/\varepsilon$, and the real growth rate g. In steady state, consumption growth is equal to the growth rate of capital per worker, both of which are independent of the population growth rate n. For every percentage point increase in GDP growth, the real interest rate must thus increase by ε percentage points (Aghion and Howitt, 2008). Empirical estimates of the elasticity vary, but suggest that it might be usually smaller than unity. Havranek et al. (2015), for example, find in a meta-study a value of about two for ε. Consequently, just as in the Solow-Swan model, a one percentage point change in real GDP growth should lead to a more than one percentage point change in real interest rates. Furthermore, the elasticity of the real interest rate with respect to the growth rate seems to be larger than in the Solow-Swan model. An additional requirement of the model is that the following condition holds in equilibrium: $r > n + g$, meaning that the return to capital should be greater than the sum of the rate of technological change and the population growth rate (Baker et al., 2005; Aghion and Howitt, 2008).

The Cass-Koopmans-Ramsey model features one representative household. Baker et al. (2005) make a slight modification to the model, which allows for exogenous population growth. Moreover, they adopt a version of the model where the household's utility function includes a discount factor that is dependent on the rate of population growth. The authors describe this addition as one of "imperfect altruism" (Baker et al., 2005). In the baseline model, the utility of all future descendants is discounted at an equal rate. Since population growth is dependent on the rate of migration and thus the arrival of strangers, this might be not be the most straightforward way to think about future generations. In a way one can describe this modification as discounting the utility of strangers to a greater extent: In that particular version of the model, consumption decisions are not independent of population growth anymore. As a result, the real interest rate is also positively correlated with the rate of population growth just as the standard Solow-Swan model predicts. The canonical Euler equation adopted for population growth then becomes:

$$r = \rho + \varepsilon * g + \beta * n \tag{18}$$

where the parameter β corresponds to the parameter on population growth (Baker et al., 2005). There are to our knowledge very few empirical estimates on the size of the β parameter. Rachel and Smith (2015) emphasize that lower population growth should reduce the marginal productivity of capital if capital and labor are substitutes in the production function, which is a priori a reasonable assumption. Rachel and Smith (2015) thus suggest that $\beta > 0$. On the other hand, a one-to-one mapping between population growth and real interest rates seems to be rather unlikely. Therefore the authors also put an upper bound of $\beta \leq 1$ on the population growth parameter (Baker et al., 2005). Note, however, that this assumption is in contrast to the prediction of the classical Solow-Swan model where the population growth parameter reduces real interest rates by a factor of α/s, which in all likelihood exceeds unity.

Last but not least, the standard overlapping generations model (OLG) makes also clear predictions about the relationship between the real interest rate and our key parameters of interest. Baker et al. (2005) show that the real interest rate is a positive function of productivity growth and population growth. Especially more recent OLG models with different cohort sizes, such as Lu and Teulings (2017) and Eggertson et al. (2017), predict a "secular stagnation" outcome with negative real interest rates as a result of negative population growth (with young cohorts being smaller than the old cohorts).

To sum up, neoclassical long-run growth models predict a positive long-run relationship between real interest rates and GDP growth as well as population growth rates. The different models, however, make different predictions about the elasticities. In the standard Solow-Swan model, reductions in GDP growth and population growth affect the real interest rate by the same factor $\frac{\alpha}{s}$, which might take on a value of about 1.5. The Cass-Koopmans-Ramsey model, on the other hand, suggest that changes in GDP growth rates should affect the long-run real interest rate to a much larger extent than changes in the population growth rate. The exact size of the coefficients is thus ultimately a matter of empirics.

The issue of secular stagnation

Neoclassical growth theory makes clear predictions about the long-run relationship between real GDP growth, population growth, and the return to capital. More specifically, in the Solow-Swan growth model, we have that the following relationship our key parameters of interest:

$$(19) \quad \Delta r = \frac{\alpha}{s} * (\Delta \mathrm{n} + \Delta \mathrm{g} + \Delta \mathrm{d})$$

If the economy is dynamically efficient, i.e. if the savings rate is smaller than the capital share, then any percentage point reduction in the growth rate of GDP must reduce the real return of capital by more than one percentage point. The same can be said for changes in the population growth rate.

More recently, some economists have argued that we are currently facing a prolonged period of secular stagnation. Gordon (2017) has pointed out in his book that the golden age of productivity growth is over. According to his view, GDP growth is more likely to decelerate than accelerate in the years to come. Most of the general purpose technologies were invented in the 20th century. Lawrence Summers (2014) has made similar arguments. He recently revived the theory of secular stagnation, according to which most advanced economies will face a prolonged period of demand-side stagnation in the current macroeconomic environment. Many factors, ageing populations, increased inequality, rising monopoly power, have increased the desire to save while at the same time leading to a reduction in desired investment. The resulting imbalance between savings and investment has resulted in a decline in the equilibrium real interest rate. Moreover, the effective lower bound on nominal interest rates represents a constraint on how far real interest rates can turn negative if Central Banks are unable or unwilling to generate the necessary rate of inflation to return the economy back to equilibrium (Summers, 2014; Summers, 2015).

In terms of the Solow-Swan model, historical figures suggest a value of about one third for the capital share α and a value of about 0.22 for the savings rate s, thus implying that the fraction α/s should be equal to about 1.5 (Sørensen and Whitta-Jacobsen, 2005). Many advanced economies, including the US have faced a remarkable productivity slump over the last decade. As such, the long-run real growth rate in the US slowed down from about 2% in the 1990s to less than 1% nowadays. Moreover, annual population growth has also halved from about 1.3% to about 0.7% over the same time period. These two factors alone would explain a more than 3% reduction in the return of capital (r) as well as a similar decline in the real equilibrium interest rate (r*) in the standard Solow-Swan model: (1% + 0.6%)*1.5= 2.4%. Similarly, the Cass-Koopmans-Ramsey model implies that those two factors might push down real interest rates by about 2.6% if one assumes an elasticity of two for the real growth rate and an elasticity of one for population growth rates with respect to the real interest rate as suggested above.

On the other hand, there are several factors that push in the opposite direction. One neglected macroeconomic trend is that depreciation rates have increased quite substantially in recent decades across advanced economies. While the standard neoclassical model does not make any distinction between different types of capital, there is reason to believe that this is an important factor of omission. Some economists have argued that modern ICT technologies become obsolete at a quicker pace, which in turn would raise the replacement demand for capital and thus the equilibrium real interest rate (Oulton, 2012). Similarly, an increase in the capital share α also raises the real interest rate since the parameter α corresponds to the elasticity of output with respect to capital. An increase in said elasticity raises the marginal productivity of capital and thus also increases the real interest rate. Many papers have recently examined the evolution of factor shares in the short and in the long-run and have found convincing evidence for the fact that capital shares have been increasing globally in recent decades, both in advanced as well as in emerging economies (Stockhammer, 2013). It is still disputed on why exactly we observe this phenomenon. However, insofar as the increase in the capital share actually corresponds to higher markups and rising monopoly power, one would not expect a higher equilibrium return of capital as the marginal efficiency of capital is not affected. Some authors have recently found convincing evidence for increasing monopolization in the US case, thus providing clear evidence against the baseline Solow-Swan model, which assumes perfectly competitive factor markets (Autor et al., 2017). Last but not least, a decline in the savings rate s could also lead to a higher equilibrium real interest rate. It has been argued that ageing populations may actually save less, since the working population tends to accumulate most of the capital (Lu and Teulings, 2017). As such, one could observe declining saving ratios in the US, but also in countries like France, Japan, and Italy, in recent years. A lower rate of capital accumulation increases the equilibrium real interest rate in the model as it leads to a leftward shift of the supply of capital. However, as evident in some of the OLG literature with different cohort sizes, the first-round effect of an ageing population might actually be an increase in the savings rate if the working population outnumbers the young cohort (Lu and Teulings, 2017).

To sum up, while the reduction in GDP growth and population growth have a more than one-to-one percentage point effect on the real interest rate according to the benchmark model, other factors might push in the opposite direction. Most notably, a decline in the savings rate, an increase in the capital share, or even a rise in the depreciation rate might partially offset the "secular stagnation" trend of declining equilibrium interest rates.

Measuring the real interest rate

Macroeconomic theory makes a clear distinction between ex-ante real interest rates and ex-post real interest rates. From the Fisher equation, we get that the real interest rate is equal to the nominal interest rate minus the expected rate of inflation (Abildgren, 2005):

$$(20) \quad r_{t,\ ex-ante} = i_t - \pi_t^e$$

Neo-keynesian theory suggests that a number of macroeconomic outcomes, such as consumption and investment decisions, are determined by the ex-ante real interest rate and therefore depend on inflation expectations (Sørensen and Whitta-Jacobsen, 2005). While modern financial markets allow us to measure inflation expectations directly via the spread between normal and inflation-protected Treasury securities (the so-called TIPS spread), for example, it is extremely difficult to obtain accurate historical measures for inflation expectations going back further in time. As a consequence, we use the ex-post real interest rate in our third paper, which is simply the nominal interest rate in a given year minus the realized rate of inflation:

(21) $r_{t,\ ex-post} = i_t - \pi_t$

Moreover, there is a clear distinction between short-run and long-run interest rates, as measured by the return on government securities of different maturities. It is usually the case that the term structure of the interest rate is upward sloping, i.e. that long-term rates are higher than short-term rates, because investors have to be compensated for the extra risk of bearing securities that have a longer maturity.

Open-economy considerations and idiosyncratic risk factors

We have previously assumed that the real interest rate is solely determined by domestic factors. In a world with perfectly free capital mobility, on the other hand, domestic interest rates should be equal to the world interest rate. In other words, small and open economies have no influence on the rate of return as capital is chasing around the world to equate marginal products. The Solow-Swan model for the open economy literally implies that steady-state values are reached immediately and that the real interest rate for a small open economy is equal to the global real interest rate (Sørensen and Whitta-Jacobsen, 2005). While in a closed economy, savings and investment are necessarily equal, the current account is the difference between the two in the open economy case:

(22) $CA = S - I$

The net addition to the domestic capital stock is thus the domestic savings rate plus the inflow of capital from abroad, i.e. the negative of the current account (Sørensen and Whitta-Jacobsen, 2005).

(23) $I = S - CA$

On the one hand, financial markets have become increasingly open and integrated. More recently, Jorda et al. (2017a) have documented that cross-country correlations of stock market returns have increased a lot in recent decades. Housing returns, on the other hand, seem to be much less correlated across countries and more determined by domestic factors, thus presenting an obvious investment opportunity from a risk diversification point of view. While financial markets are increasingly integrated, economists have observed for a long time that domestic investment rates and domestic savings rates are highly correlated, the so-called Feldstein-Horioka puzzle (Rogoff and Obstfeld, 2000). Needless to say, that in the presence of risk and uncertainty, home bias when it comes to investment decisions, credit constraints, and imperfect capital markets in general, the correlation between domestic investment and domestic savings should be much stronger. Consequently, most researchers have adopted an intermediate position where domestic real interest rates are determined both by domestic and international factors (Bosworth, 2014).

While it is commonly assumed that US government bonds are safe assets, this is certainly not the case for all countries during all time periods. During the Euro crisis, one could observe quite large deviations between interest rates of member countries, which was due to variations in risk premia (Lane, 2012). As such, the real interest rate for country i includes the country-specific risk premium ε_i that compensates investors for the additional risk they have to bear in the case of investing in a more unsafe asset class:

$$(24) \qquad r_i = r_{globall} + \varepsilon_i$$

There is no doubt that the risk premium is country-specific and can vary over time. US government bonds as well as German Bunds are typically regarded as safe assets. On the other hand, during the Euro crisis certain Southern European countries like Spain experienced a sort of "run" on their debt obligations as investors were fleeing to safety. Consequently, interest rates spiked in Southern Europe as a consequence of higher risk premia. Diverging interest rates in the Eurozone were finally reversed once the ECB provided a backstop on Southern European debt obligations by starting its asset purchase program, also known as Quantitative Easing (Baldwin and Giavazzi, 2015).

Different types of capital

While neoclassical growth models do not distinguish between different types of capital, there is no doubt that different asset classes yield different returns. Investors have to be compensated for the additional risk they bear by holding securities of longer maturities, thus explaining the difference in yields between bills and bonds (Sørensen and Whitta-Jacobsen, 2005). However, this difference can vary widely and also depends on economic conditions. Jorda et al. (2017a) document that historically the term premium has been relatively low over the last one hundred years. Only during the last three decades as well as during the interwar period one could observe a significant difference in returns between bills and bonds. The risk premium measures the difference in returns between safe assets, such as bonds, and riskier assets, such as stocks and real estate. The size of the equity premium, the difference between safe and risky rates, is one of the big puzzles of macroeconomics (Mehra and Prescott, 1985). Jorda et al. (2017a) show that the risk premium has historically been extremely high with an average rate of 4 to 6% across their panel of advanced economies. Again, historical variations have been relatively large with risky returns outpacing safe returns by up to 10% during the postwar period. While the risk premium was lower during the Great Moderation, it has increased again in the aftermath of the Global Financial Crisis with the safe rate of return falling to extremely low levels (Caballero and Farhi, 2014).

Cross-country correlations between real returns

While the more simplistic macroeconomic models tend to assume that risk-adjusted returns in a perfect world without capital restrictions and other frictions are equalized across countries, the empirical evidence shows that things are not quite so simple in reality (Sørensen and Whitta-Jacobsen, 2005). Jorda et al. (2017a), for example, have gathered evidence for stock market returns, housing returns as well as the interest rate on bonds and bills for 17 countries from 1870 to today. The authors claim that there have been significant divergences across countries in terms of asset price performance, both across time and space. However, the data also reveals that in our world of rising capital mobility, asset price returns tend to be increasingly correlated (Jorda et al., 2017a). Furthermore, the international business cycle seems to play an increasing role, especially for small and open economies, which are highly dependent on international trade flows and global capital flows. The evidence also shows that business cycles across countries tend to become synchronized as a result, which would explain the higher correlation of asset prices as well (Jorda et al., 2017b). Ironically, in our world of globalized capital, the benefits from international diversification might then actually be reduced if international asset price returns become increasingly correlated, with real estate being the notable exception because it depends to a much greater extent on domestic conditions (Jorda et al., 2017a).

Explanations for high asset prices and declining real interest rates

While we have established above that conventional long-run economic growth models imply a decline in future real interest rates as well as a decline in the real return of capital, this prediction has so far not come to fruition. To the contrary, asset prices have soared across most advanced economies in recent decades. This is especially true for stocks but also for real estate. Jorda et al. (2017a) document that the long-run inflation adjusted return on both assets has historically been well above 7%. Moreover, asset prices have performed particularly well since the early 1990s (Jorda et al., 2017a) despite the fact that many advanced economies have experienced a remarkable productivity slowdown combined with declines in population growth rates. We will provide several different macroeconomic explanations that can explain this anomaly, which belong to the following categories:

1. Rising risk premium
2. Rising markups
3. Lower equilibrium real interest rates
4. An increase in agglomeration economies combined with a static supply of housing in the large metropolitan areas
5. Increasing financialization, allowing for a higher private sector debt and mortgage share of GDP, thus also supporting rising asset prices
6. An increasing capital share of GDP

1) Risk premium

Many economists have argued that the Global Financial Crisis has led to an increase in the demand of safe assets (McCauley et al., 2008). Following the financial shock, macroeconomic uncertainty increased and the demand for safe government securities while at the same time the supply of assets previously considered safe, such as triple A-rated mortgages, declined substantially. Moreover, following the Basel regulations banks, insurance companies, and pension funds and other financial entities were also required to hold more government securities. This is the so-called safe asset shortage, suggested by Caballero and others (Caballero and Farhi, 2014; Caballero et al., 2016).

All these factors combined can explain why as of 2017 there were still about 10 trillion US-dollars worth of bonds with negative nominal yields (Gutscher, 2019). The rise in the risk premium has the effect of driving a larger wedge between the return of safe assets and more risky ones, such as stocks. Jorda et al. (2017a) have documented that the risk premium was declining and relatively small by historical standards in the run-up to the Global Financial Crisis, thus suggesting some kind of Minsky cycle at work (Knell, 2015), whereas in the aftermath of the crisis the risk premium has risen quite substantially.

2) Rising markups

The baseline assumption of perfectly competitive factor markets in the Solow-Swan model is a relatively large sin of omission. More recently, several studies have documented an increase in markups across industries in the US (Barkai. 2016; Dorn et al., 2017), a phenomenon that might also be more global in nature and could have contributed to the declining labor share across many countries in recent decades. Let us assume that total economy-wide output is equal to the factor shares plus monopoly profits Π:

$$(25) \qquad Y = wL + rK + \Pi$$

It can be shown that within a relatively simplistic model, using a CES aggregate production function, that the rental rate of capital r as well as the real wage w are both a declining function of the markup, which is a proxy for monopoly power (Grenestam and Probst, 2014). An increase in markups across sectors therefore increases the profitability of firms by increasing economy-wide rents while at the same time decreasing both the labor share and the capital share of GDP. Rising monopoly power would thus have the tendency to depress the pure rental rate of capital. However, it also drives a wedge between the equilibrium rate r* and observed stock market returns (Dorn et al, 2017).

3) Lower equilibrium real interest rates

A lot of research has shown that global natural or Wicksellian real interest rates have fallen quite significantly over the last few decades (Rachel and Smith, 2015; Summers, 2015). While real interest rates were around 3 to 4% across advanced economies in the late 1980s, they have fallen to zero percent in the aftermath of the financial crisis. Many Central Banks have therefore struggled with the zero lower bound on interest rates. The decrease in equilibrium interest rates across advanced economies has the perverse effect of leading to lower returns on safe assets, mostly government bills and bonds, while at the same time increasing the return from risky financial assets, such as stocks and real estate, and therefore driving a wedge between the two (Summers, 2015). Given that the value of any financial asset is simply the discounted value of all future cash flows, lower interest rates have the side effect of increasing the fundamental value of stocks and real estate. The increase in asset prices that has taken place in recent decades, especially when it comes to housing and stock prices, is therefore also a function of the Wicksellian interest rate that has continued its downward trend and now seems to hover just above zero in many advanced economies. According to Larry Summers' (2014) theory of secular stagnation, many of the aforementioned structural factors like adverse demographics and low productivity might be expected to stay with us for quite some time. Consequently, we can expect in the future a macroeconomic regime characterized by elevated asset prices across the board and low equilibrium interest rates, meaning that advanced economies might therefore be much more prone to financial bubbles than previously acknowledged (Krugman, 2014; Summers, 2015).

4) Agglomeration economies and their effect on house prices

From a structural point of view, most advanced economies seem to have undergone some fundamental changes that started in the 1980s. Many studies have confirmed that economic concentration has increased significantly despite the emergence of the new internet-based economy (Glaeser, 2012). In fact, Moretti (2014) and others (Florida, 2017) have argued that it is precisely because of the emergence of the new economy that economic activity has become more "spiky", using Richard Florida's terminology (Florida, 2017). Local knowledge hubs have increasingly driven GDP growth while the more rural parts of the economy have lagged behind. In the US case, even a significant share of the small and medium-sized cities have fallen behind in terms of employment growth and wage growth (Moretti, 2014). Economic production has become increasingly concentrated in the technology hubs and financial, such as Silicon Valley, Seattle, New York, Austin, Toronto, just to name a few of the most important ones in America (Moretti, 2014). Furthermore, this phenomenon is not only US-specific. In Europe, one can observe a similar trend with the metropolitan areas of Paris and London now producing more than 20% of national output, a tendency that does not seem to come to a halt anytime soon as this share is expected to increase even

further. Agglomeration forces and the rise of the mega-regions (Florida, 2008), based on the production of knowledge, combined with the positive amenities that these cities seem to offer, have therefore been the driving force in shaping the global economies in recent decades. The clustering of economic activity has led to a rise of a few superstar cities where both superstar firms and superstars talents are located, thus also leading to an increase in inequality within most advanced economies. These forces might ultimately also even drive election outcomes and can explain the recent rise in populism across advanced economies (Florida, 2017).
The aforementioned increase in agglomeration effects also had the effect of pushing up real house prices in the metropolitan areas by a larger extent than what the national house prices series suggest. The core issue is, of course, the continuing rise in demand whereas the supply response has simply been insufficient, thus driving up prices. This is an international phenomenon that even affects small and open economies like Denmark and Sweden. As such, house prices in Stockholm, Gothenburg, and Copenhagen, for example, have risen significantly faster in real terms than in the rest of Sweden and Denmark. Furthermore, Scandinavian house prices seem to be supported by an enormous amount of mortgage debt (Abildgren, 2010), given that the mortgage to GDP ratio approaches or even exceeds one year of GDP and is thus significantly higher than in most other advanced economies, including the US (Jorda et al., 2013).

5) Increasing financialization

A large body of economic literature has observed the increase in private sector debt, both across advanced economies and emerging markets, since the end of Bretton Woods. A significant portion of the increase can be attributed to private sector mortgages (Jorda et al., 2015; Jorda et al., 2017b). Compared to some other Western economies, the US housing bubble and the mortgage to GDP ratio in the US economy actually look relatively benign. It is especially in the Scandinavian economies as well as in Australia and Canada where private sector debt has been on an explosive path, with the economy-wide mortgage to GDP ratio approaching 100% (Jorda et al., 2015). The increasing financialization of real estate and the easing of credit conditions in these countries have certainly led to a dangerous feedback loop between rising house prices and rising debt levels (Turner, 2015). The long-term decline in interest rates across advanced economies exacerbated the trend by simultaneously decreasing the opportunity costs of taking out mortgages (and other forms of debt) while at the same time putting upward pressure on global real estate prices (Turner, 2015).

6) The rising capital share of GDP

Finally, the simple Solow model suggests that a rising capital share of GDP, the share parameter α in the production function, actually leads to an increase in real interest rates (Baker et al., 2005). However, here one must distinguish between returns on risky capital, and the safe rate of return or the equilibrium interest rate r*. Furthermore, causality can also run in both directions. As we will show in one of the papers, rising asset prices and higher returns on risky capital can increase the capital share of GDP. However, this finding can still be consistent with the fact that a number of structural factors push down the equilibrium interest rate at the same time, as we have argued above. It is thus entirely feasible that some factors have driven a wedge between the return on different kinds of capital with different risk profiles, thus consistent with the hypothesis of a rising risk premium (Jorda et al., 2019). An increase in the capital share can therefore lead to higher returns on stocks and real estate despite the global decline in the return on safe assets, meaning government bonds.

Concluding remarks on interest rates

While our analysis above provides us with an explanation for the decline in global real interest rates based on neo-classical growth models, the data also shows that the correlations that these models predict cannot always be confirmed empirically. Some empirical research has established that the correlation between output growth and real interest rates, for example, is relatively weak (Bosworth, 2014). This seems to be true both on the country level and on the global level. Furthermore, some of the variables, such as population growth, are relatively slow-moving. While some authors have suggested that a vector-error correction model (VECM) can identify equilibrium relationships between our aforementioned variables and the real interest rate, such a method also suffers from a number of drawbacks. First, when using annual data, there are simply very little observations when estimating the model on the global level, especially if one tries to do so by splitting up the sample according to the different global monetary regimes that have existed since 1870. Second, sometimes VECMs identify more than one cointegration vector between variables. This poses a problem from an analytical point of view, since it is then not clear which of the equilibrium relationships is the "right" one (Enders, 2008).

Consequently, we have chosen to pursue an alternative approach in our paper on real interest rates where we employ the time series factor methodology mentioned previously to examine to what extent national real interest rates are dependent global variables. As outlined in our theory, the global real interest rate will be one of the most important determinants of national real interest rates, especially during times of high capital mobility when global macroeconomic factors will trump domestic macroeconomic conditions, particularly in the case of small and open economies.

Zipf's law and random growth theory

The literature on urban economics is very extensive, as many researchers have emphasized in recent decades the strong correlation between urbanization and economic development (Glaeser, 2012). Furthermore, it has been found that large cities are more productive in general. The economic literature on agglomeration economies has increased dramatically, also emphasizing the strong link between local knowledge hubs and technological clusters and regional variations in income growth (López Cermeño, 2017; Lee, 2019). It is especially in recent years with the introduction of the knowledge economy that regional economic centers based on knowledge-intensive industries have flourished at the expense of the older industrial clusters (Moretti, 2012). In that way, many large metropolitan areas have outpaced rural regions as well as many small cities in terms of regional economic development and income growth, However, this also resulted in dramatic increase in local house prices in the affected communities (Florida, 2017).

Within the literature of urban economics, a large subset of the research is devoted to explaining the phenomenon of Zipf's law, a well-known empirical regularity in urban economics concerning the rank-size distribution for cities. Zipf's law basically describes a power law distribution for city sizes within a particular region or country (Krugman, 1996; Venables, 2007; Gabaix, 1999a; Gabaix, 1999b). More specifically, for many urban hierarchies, economists have established that the rank-size rule commonly assumes a coefficient roughly equal to one in absolute values. This implies that within the urban system the second city is approximately 1/2 the size of the primate city in terms of population and the third city is approximately 1/3 the size of the primate city, etc. Consequently, the n^{th} city in the urban hierarchy should be about 1/n the size of the primate city if Zipf's law roughly holds. While many economists have established this empirical regularity using more contemporary data for urban populations (Venables, 2007), some economic historians have started to examine the rank-size rule using historical data for urban population growth in early modern Europe (Gonzalez-Val, 2016).

From a theoretical point of view, it is not entirely clear why the city size distribution tends to follow a power law with the particular slope coefficient close to one in most cases (Gabaix and Ioannides, 2004), even though many economic phenomena can be described by a power law relationship (Gabaix, 2009). From a mathematical point of view, power laws occur naturally as a result of random growth (Gabaix, 2009). It is thus ultimately not surprising that stochastic growth processes occur throughout a very wide range of socio-economic phenomena (Gabaix, 1999b). Therefore, power laws can describe the size distribution of US firms by number of employees (Steidl, 1965; Gabaix, 2009), but also the cumulative distribution of daily stock market returns, the distribution of wealth and income within a society, to just name a few applications (Gabaix, 2016; Piketty and Zucman, 2014). While for many of these cases the power law coefficient is above unity, many studies have confirmed that for the city size distribution the power law coefficient is very often equal as argued above (Gabaix, 1999a), thus leading to the peculiar effect that the n^{th} city in the city network is 1/n the size of the first in terms of population size (Venables, 2007).

Gabaix (2009) derives the power law relationship and shows that Zipf laws holds exactly if the stochastic growth process holds throughout the entire city size distribution, meaning that the normalized population growth rate must be an independent and identically distributed random variable (i.i.d.), a proposition that has been called Gibrat's law (Gibrat, 1931). Zipf's law, the power law with a coefficient equal to one, then holds exactly if some minor frictions are introduced in the lower tail of the distribution. Of crucial importance is here the assumption that small cities cannot get too small, a mechanism that can be explained via lower rent and housing costs, for example, which would help stabilize small-sized cities with a certain population threshold (Gabaix, 2009).

However, more recent studies have also revealed that the assumption of random growth cannot always confirmed empirically, especially in the presence of more severe market frictions (Gabaix, 2009; Dittmar, 2011). First, cities in the lower part of the city size distribution most often tend to have a larger variance in terms of population growth rates, thus violating Gibrat's law. Therefore, in many cases Zipf's law only seems to hold exactly when researchers restrict the city sample size to the large cities in the city network while excluding the lower tail (Gabaix, 2009). Second, when frictions are large, deviations from Zipf's law are to be expected. Dittmar (2011) has shown that market integration is crucial for the establishment of the power law relationship for the city network in early modern Europe. If the variance of the population growth rate is somehow dependent on initial population size, then the slope coefficient of the power law would vary between different percentiles in the city size distribution, thus explaining departures from Zipf's law (Gabaix, 2009; Dittmar, 2011).

First- and second nature geography

The explanation of a purely stochastic growth process is obviously not quite entirely satisfactory as an economic hypothesis for the growth of cities within a particular country and region. Krugman (1996) therefore suggests that it might be geographic forces after all that are the fundamental driver behind this peculiar relationship. He determines that it is the random distribution of natural landscapes, or first-nature geography, which is shaping the city size distribution. More specifically, the occurrence of natural landscapes leads to randomly varying transport costs within a particular region, which then can explain the underlying stochastic growth process (Krugman, 1996). This explanation has the obvious advantage of tying random growth to geography, which is advantageous given the more recent emphasis on the importance of first- and second-nature geography for economic growth processes. A large body of research suggests that first-nature geography was of crucial importance for the early days of modern development (Diamond, 1998; Morris, 2010). Most Roman cities, for example, were located at the sea or large rivers in continental Europe, given that trading and transportation by ship was significantly faster and more efficient this way (Duncan-Jones, 2002). This, in turn, has shaped the city network in Europe for many centuries (Dalgaard et al,. 2018). Moreover, some research has suggested that cities can actually get trapped in a sub-optimal location. Most French cities inland were built on the remains of Roman settlements whereas the British city network was entirely reset during the Medieval Ages, thus giving the country a natural advantage since the new towns were placed in more favorable locations alongside navigable waterways, which had an impact on subsequent population growth of these towns (Michaels and Rauch, 2014).

It is only since the beginning of modern economic growth, and especially in recent decades, that second-nature geography has started to trump first-nature geography, since agglomeration economies have become increasingly important (Glaeser, 2012; Moretti, 2012; Redding, 2010). Some more recent research has emphasized the importance of local knowledge hubs for regional development (Moretti, 2012). While many mid-sized towns in the US have stagnated in recent decades, it is the cities that have good universities that perform a lot of research, which have performed much better than cities that rely on an old industrial base. Spillovers from these knowledge hubs are leading to new economic clusters based on research and innovation (López Cermeño, 2017), two factors that have become increasingly important, given that industrial production has been outsourced to a great extent to South-East Asia (Baldwin, 2016).

Despite ongoing structural changes within the economy over the course of several centuries, historical papers have emphasized that Zipf's law was already holding in Western Europe during the early modern period (Gonzalez-Val, 2016). Furthermore, the existence of the power law seems to be closely linked to market integration, given that the power law relationship only established itself in Eastern Europe a couple of centuries later (Dittmar, 2011). Historical research has shown that the Elbe River was an important geographic boundary and that institutions in Eastern Europe, especially serfdom, non-existent property rights, etc., were much less conducive to economic growth and market integration, in general (North, 1973). First- and second-nature geography effects therefore also seem to be important factors in determining the city size distribution within a particular region or country, thus leaving some space for economic geography considerations as an explanation for the rank-size relationship (Krugman, 1996; Gabaix, 2009).

Summary of the research articles

The following section presents an executive overview of the four research articles of my thesis. The abstracts of the four papers below contain the research question, a summary of the most important results of the research, the contribution to the literature, potential policy implication, and potential avenues for future research.

Paper 1: The decline of the US labor share, depreciation, and imputed housing costs

It is well known that the labor share of income has fallen quite significantly in many countries in recent decades (Bengtsson and Waldenström, 2015). A lot of research has focused in one way or the other on the decline of workers' bargaining power, either being the result of the erosion of labor unions (Fichtenbaum, 2011), global offshoring, a rise in companies' market power (Barkai, 2016), or increasing financialization (Stockhammer, 2013). We argue that most of these explanations seem to be insufficient to explain a large part of the fall of the labor share for the US case. Moreover, all these competing theories cannot be true in aggregate. The aim of this research paper is to show that two simple factors alone can explain most of the decline in the US labor share, namely a drastic increase in consumption allowance of fixed capital (depreciation) and the rise in imputed rents, both of which are included in GDP, but are technically not an income stream to any factor of production (Rognlie, 2015). We argue that net of depreciation and imputed rents, factor shares might have actually remained relatively constant in many countries. We examine depreciation rates by sector and by asset class for the US economy. The data from the BEA shows that depreciation rates have increased significantly across all industries in the postwar period, thus partially explaining the fall in the gross labor share, both at the aggregate level as well as within sectors. The increase in depreciation rates seems to be crucial macroeconomic trend that has not yet received the widespread attention it deserves in the macroeconomic literature. We also provide tentative answers as to why deprecation rates have increased in aggregate. A decomposition of depreciation rates by asset class shows that it is mostly the rise of intangible assets that has produced the economy-wide increase in the depreciation rate (Koh et al., 2015). Especially countries like the US have moved away from a classical production economy towards a knowledge-intensive economy. Intangible assets based on groundbreaking ideas and innovations, patents, software, and even brand values have become increasingly important. A brief look at today's US stock market shows that the most valuable companies nowadays aren't anymore the ones that employ capital-intensive production methods, such as General Motors, or General Electrics. Instead, companies that depend on the production of intangibles and knowledge in general, such as the likes of Facebook, Apple, Amazon, Google, and Microsoft, have become much more valuable, with some of them reaching the one trillion dollar valuation recently. The net stock of intangible assets has increased from a negligible amount to about 15% of GDP in the US in recent years. The increasing importance of these assets raises a number of conceptual questions:

1) How can the economic value of these assets be assessed if no fair market value exists?
2) Do firms have an incentive to overestimate their depreciation expenses in order to increase their cash flow and reduce their tax liability?
3) What kind of distortions result from international firms shifting their intangible assets and therefore also part of their profits to tax-havens like Ireland?

While the BEA data clearly reveals a substantial increase in depreciation, both at the aggregate level as well as at the sectorial level, there is some reason to believe that part of the problem is the increasing disconnect between depreciation as an accounting concept and depreciation as a true economic cost of production. Changes to the tax code in the early 1980s, for example, have allowed companies to depreciate some of their assets at a significant faster rate than what was previously allowed, thus allowing companies to increase their cash flows at the expense of a decrease in the taxable corporate profit. However, there is also some reason to believe that the increased economy-wide depreciation share is actually the result of secular structural changes in the economy. First, an increase in the capital stock would tend to lead to a higher depreciation share even if the actual underlying depreciation rate remains constant. Second, a compositional shift towards different production methods by employing more faster-depleting capital would also raise the aggregate depreciation share. Both companies and consumers are using more capital-intensive assets that are becoming obsolete at a much faster rate. These are items, such as computers, smartphones, and software, all of which have an extremely low average lifetime compared to other industrial equipment, simply because they become outdated very quickly. The shift towards these kinds of assets and the increasing importance of intangibles and Intellectual Property has therefore resulted in an increase in depreciation shares across advanced economies.

We also show in the paper that the rise in imputed rents in recent decades has been a second contributing factor in the decline of the gross labor share in the US. While the rental income share of GDP has stayed fairly constant, imputed rents have increased significantly from above 6% of GDP a few decades ago to about 8% of GDP as of today (La Cava, 2016). Internationally, there are several ways on how to measure imputed rents and the exact method differs somewhat by country and statistical agency. In general, imputed rents are either measured with the rental equivalence method, or alternatively by estimating the user cost of housing services. In the US, the BEA infers imputed rents by comparing owner-occupied housing with equivalent dwellings in the rental market. The recent house price booms that the US and other countries have observed obviously contribute to the phenomenon since rising house prices ultimately translate into higher rents, and therefore also imputed rents. Consequently, one can observe a significant increase in the rental income share of GDP, with most of the increase in the US being attributed to owner-occupied housing. We also provide some international evidence on how expenditures on housing services have increased across advanced economies, thus putting some downward pressure on the gross labor share. The evidence seems to suggest that a substantial fraction of the decline in the gross labor share can be explained by two factorless income streams, namely rising depreciation and imputed rents. Netting out these two factors, the labor share has stayed relatively constant and the significant downward trend observed since the 1980s disappears. While is not entirely clear whether the gross or the net labor share is the more relevant measure for inequality, house price booms in the advanced economies have the obvious effect of increasing wealth inequality, since property owners tend to belong to the richer part of society. The younger generation, on the other hand, is increasingly priced out of the property market, and home ownership of millennials is much lower than home ownership was for the baby boomers, for example, when they were at the same age. While we have established that depreciation, especially of intangibles, is an important factor, more research is needed on how firms shift these assets to tax-havens and to what extent this tax-optimizing behavior produces distortions in the national accounts and international capital flows between countries (Zucman, 2014).

Paper 2: Financialization, asset prices, and the functional distribution of income: A long-run cross-country analysis

In this paper, we establish a link between rising asset prices and the functional distribution of income, using long-run macroeconomic data that goes back to the late 19th century. We rely on the Bengtsson-Waldenström database for historical capital share data for our sample of 17 advanced economies. We use the Jorda, Schularick and Taylor Macrohistory (2016a) data for asset prices (stock prices and housing prices) as well as for other macroeconomic variables that we use as controls in our estimation methods.

One should note that our panel approach hides cross-country heterogeneity by design, meaning that we estimate a marginal average effect across our sample. The problem one commonly encounters in empirical macroeconomics is that the number of observations is small, especially when one uses annual data. The panel-approach can thus lead to a more efficient estimation and also help us uncover systematic macroeconomic relationships that might be hidden by idiosyncratic shocks (Gavin and Theodorou, 2005). We estimate the relationship between monetary variables, credit, asset prices, and the functional distribution of income within a Panel-Var framework, which assumes that all these variables are determined endogenously within the macroeconomy. While the model thus imposes a specific structure, it helps us to uncover relationships based on the Granger causality concept as well as impulse response functions (Goodhart and Hofmann, 2008).

We find the anticipated positive effect between nominal stock price growth and the capital share, and we can also confirm Granger causality between those two variables. Our estimated impulse response functions suggest that an innovation to stock price growth leads to an increase in the capital share of about 0.6 to 1.5 percentage points within the subsequent two to three years. While the exact size of the effect is somewhat dependent on the subsample in question, the differences in magnitude are actually not that large. On the other hand, we cannot detect any positive effect of house prices on the capital share.

We also use a more common Panel-OLS model with country and time fixed effects and country-specific time trends to support our previous results. We validate the positive expected relationship between stock prices and the capital share across various specifications. Furthermore, stock prices seem to have a positive short-run effect on the capital share also across the different macroeconomic regimes for which we estimate the regressions. According to our Panel-OLS results, an increase in nominal stock prices of 10% is associated with an increase in the capital share of about 0.1 to 0.2 percentage points in the short-run. However, the link between house prices and the capital share is less clear and also not robust. We cannot confirm any positive link between rising house prices and the capital share of income for all time periods before Bretton Woods. This result actually makes sense insofar as house prices across advanced economies have remained fairly stable, adjusted for inflation, for almost an entire century prior to the end of Bretton Woods in 1973. It is only in recent decades that real house have increased dramatically. Increasing financialization has resulted in a significant increase in private sector debt, mostly the result of house mortgages. Cheap credit has thus supported higher house prices and vice-versa, given that the value of the underlying real estate can also serve as collateral for loans and credits (Tuner, 2015; Mian and Sufi, 2015). Furthermore, the liberalization of global capital flows has increased the co-movement of international asset prices, mostly stock prices but also real estate, and it has also increased the co-movement of the national business cycle by deepening trade and financial linkages amongst countries (Jorda et al., 2017b). Using OECD data for the capital share instead from 1970 onwards, we find some evidence that real house prices are also positively correlated with the capital share. While the effect of stock prices on the capital share seems to be very robust, also across different subsamples in our study, house prices might only have become an important factor in recent decades. It should also be noted that the structure of the national housing market is of particular importance. While there is significant cross-country heterogeneity, some countries like the US have home ownership rates in excess of 60%. The largest part of the housing market is thus based on home ownership. While imputed rents are not a real income stream, they are included in the national GDP figures. As outlined in the first paper, US real estate has had a significant impact on the labor share by affecting the value of imputed rents, which increased from about 6% of GDP in the 1970s to something like 8% of GDP as of today. Given that imputed rents are based on real estate prices, there is no doubt that this phenomenon has played out in other advanced economies that have experienced similar or even more pronounced house price booms.

The current low-growth and low-interest rate regime, a global phenomenon sometimes referred to as "secular stagnation", also supports rich asset valuations worldwide (Summers, 2015). That is because low real interest rates increase the discounted value of all future income streams of any financial asset, be that stock prices or property prices (Sørensen and Whitta-Jacobsen, 2005). Given the positive relationship between asset prices and the capital share we have established, there is reason to believe that secular stagnation has also affected factor shares by tilting income away from labor and towards capital. One avenue for future research could be to quantify within a macroeconomic model the precise effect of a decline in real interest rates on the valuation of asset prices. An increase in the wealth to GDP ratio would then also affect factor shares, unless the aggregate production function of the economy is Cobb-Douglas in the medium to long-run (Jones, 2003).

Paper 3: Global real interest rate dynamics from the late 19th century to today

There is a lot of economic literature describing to what extent interest rates are determined by domestic versus international forces (Bosworth, 2014), given that capital flows would have the tendency to equalize net returns across countries. However, there is also some debate how quickly and how efficient such an adjustment process can be (Frankel, 1992), especially during times when capital flows are somewhat restricted, such as during the period of Bretton Woods. The aim of this paper is to establish to what extent national real interest rates are determined by global variables across different macroeconomic regimes. Using a time series factor model, we estimate two common global factors for the real interest rate for a panel of 17 advanced economies from 1871 to 2013. Our analysis shows that more than 50% of the variation in national real interest rates can be explained by our two international factors alone across the entire time period. Our data encompasses several macroeconomic regime changes, spanning from the time period of the classical gold standard to the more tumultuous interwar period. The global monetary system underwent significant changes after World War II when the Allied Nations under the leadership of the UK and especially the US were thinking about a new political and economic world order after World War II. During the conference of Bretton Woods, it was agreed that exchange rates should be pegged to the dollar, which itself would be convertible at a fixed price into gold. Of course, such a system would only work if capital flows were restricted as to be able to maintain the pegs. In 1973, the system broke down as the dollar's convertibility into gold was not credible anymore and most advanced economies allowed their currencies to float (Eichengreen, 1998).

We find in general that real interest rates are more responsive to international conditions during times of high international capital mobility, such as the post Bretton-Woods era. Our first common global factor can be interpreted as the global equilibrium real interest rate. We find that this factor variable can explain, on average, some 58% of the variation in national real interest rates during the tumultuous interwar period from 1914 to 1944. For the time period of fixed exchange rates and limited capital mobility, on the other hand, the global factor variable becomes much less important and can only explain some 35% of the variation. Finally, the end of Bretton Woods led to the regime of floating exchange rate and initiated an era of unprecedented financialization and capital mobility on the global level (Eichengreen, 1998). The first factor variable now explains almost 70% of the national variation in real interest rates across the sample of 17 advanced economies.

Using an error-correction approach, we also show that the global real interest rate acts as a force of attraction to national real interest rates, especially during time periods of high capital mobility. Given the small country assumption, this result was to be expected. This finding basically confirms that in case of a disequilibrium between national real interest rates and the global real interest rate, it is the national interest rate that makes the adjustment process and not vice-versa. Intuitively, most countries in my sample, with the notable exception of the US, are simply too small to have any significant effect on the global real interest rate.

Moreover, our global factor variable as well as the country factor projections show the secular decline in real interest rates that has taken place across advanced economies since the 1980s (Summers, 2014; Rachel and Smith, 2015). The forces of secular stagnation have thus acted on a global level, with some long-term and structural macroeconomic trends depressing the global natural rate of interest (Eggertson et al., 2016).

Finally, we estimate a Panel-VAR model, which allows us to show that the national business cycle is highly responsive to our two common global factor variables. This finding implies that small economies have increasing difficulties to insulate themselves from international macroeconomic conditions. This is most likely also the result of increasing co-movement of asset prices and national business cycles (Jorda et al., 2017b).

Our analysis is important insofar as it shows that during periods of high capital mobility Central Banks might have even less influence in setting domestic real interest rates, even in the short-run, than what is commonly assumed by most neo-keynesian macroeconomic models (Sørensen and Whitta-Jacobsen, 2005). While Central Banks like the Riksbank have monetary autonomy in the sense that they can for the most part determine the national rate of inflation and/or the national rate of nominal GDP growth, they must set the domestic real interest rate in accordance with domestic and international financial and macroeconomic conditions (Rey, 2016). The real interest rate is thus endogenous, also in the short-run, and our analysis shows that it is mostly determined by international factors. While this research has focused on the economic history aspect of the debate, using a panel data for 17 advanced economies from 1870 to 2013, future research could estimate the time series factor model with more contemporaneous macroeconomic data. This would allow for a greater sample size as one could include a large set of countries. Furthermore, instead of focusing on annual data, one could use monthly data for national interest rates. Both of these adjustments would allow for a much richer analysis.

Paper 4: Zipf's law for Swedish cities from 1810 to 2010

The aim of this paper is to examine the rank-size rule for the case of Sweden. We use the contemporaneous geographic boundaries of the country and rely on data sources that contain the urban population for all Swedish cities from the late 16th century onwards. We estimate Zipf's law for each decade from 1810 to 2010.

Some studies have shown that the power law is closely linked to market integration (Redding, 2010). More specifically, Dittmar (2011) emphasizes that economic integration within the urban system, the free movement of goods and even more importantly the free movement of people, is the key mechanism that leads within the urban hierarchy to a the aforementioned power law distribution.

We document the relationship for all Swedish cities from the early modern period starting from 1810 to 2010. We estimate the Zipf's law coefficient for every decade using regular OLS. As a robustness check, we also estimate Zipf's law using a median slope estimator. The latter one has been found to be more robust to outliers (Dittmar, 2011), especially for cases where the sample size is small. This is definitely a concern, given that we start with a small sample size of less than 100 Swedish cities in the early 1800s. The size of the Zipf's law coefficient can be interpreted as an indicator of population concentration within the city network. A coefficient below unity implies that that population decreases more slowly than predicted by the benchmark as one goes down in rank in the urban hierarchy whereas a large coefficient implies that population levels decrease much more rapidly between ranks. A rising slope coefficient thus indicates a tendency towards population concentration (Venables, 2007). In terms of the Zipf's law coefficient, we find some unexpected changes over the course two hundred years. The coefficient starts out with a value relatively close to unity in the early 1800s. However, it subsequently starts to increase and rises rapidly during the late

19th century to reach an all time high at around 1900. This time period corresponds to the Industrial Revolution, which occurred in Sweden a few decades later than in continental Europe. Rapid industrialization and the economic development and rising living standards that followed thus also seem to have affected the national city network. The relatively large increase in the Zipf's law coefficient indicates a tendency towards rising population concentration within the urban hierarchy, with the large cities outperforming the cities in the middle of the rank-size distribution. From 1900 onwards, however, we observe a completely different dynamic. Unexpectedly, we find that the Zipf's law coefficient has declines for most of the 20th century, thus indicating a greater tendency towards population dispersion within the urban hierarchy. This seems to be mostly the result of a number of small cities that have been added to the urban network, which have experienced above average population growth in recent decades. This is somewhat surprising given that a lot of economic research has emphasized that agglomeration effects have become increasingly important in recent decades, with the large metropolitan areas usually outperforming the rest of the country. This is a trend that has been observed for the US economy, but it equally applies to the EU and South-East Asia, and therefore seems to be global in nature (Glaeser, 2012; Moretti, 2012).

While in Sweden one can observe the clear dominance of the primate city Stockholm, with Stockholm county now accounting for almost 25% of national GDP as of 2010, the subsequent cities in the urban hierarchy all seem to be somewhat smaller than expected by the hypothetical benchmark. We find throughout the entire time period that Stockholm, being the clear primate city has a population level well-above the Zipf-consistent estimate. Many of the other cities in the upper part of the rank-size distribution, on the other hand, have population levels well-below their Zipf-consistent estimate. Again, this is a result that is quite robust and holds throughout the entire time period for which throughout the entire time period for which we have data,

Using the median slope estimator, we also find that percentile slope is extremely flat in the upper tail of the distribution, meaning that cities are more equal than what the power law predicts. Finally, using nonparametric estimator (Klein and Leunig, 2015), we show that Gibrat's law (Bertaud, 2018) is violated in the Swedish case throughout most time periods. We establish a slightly negative relationship between city rank and city growth rates throughout the 19th century, meaning that larger cities were outperforming the middle and lower part of the rank-size distribution during Industrialization in terms of population growth. This relationship reverses during the 20th century, thus pushing down the Zipf's law coefficient from its absolute high in the early 1900s. Our findings are important insofar as the paper establishes that Sweden is a somewhat abnormal case with one clear primate city, the capital Stockholm. While the subsequent cities in the rank-size distribution are smaller than their Zipf-consistent estimate, many small cities in the middle and lower part of the distribution are larger than their Zipf-consistent estimate, which could potentially even have macroeconomic implications, as we will argue below.

Concluding discussion

The first two papers of the dissertation both contribute to the growing economic literature on inequality and the functional distribution of income. Piketty's (2014) original contribution was to show that rising wealth to income ratios would have the tendency to increase the capital share of GDP across advanced economies. His particular focus was on house prices, which have experienced a secular boom since the end of Bretton Woods (Knoll et al., 2017). The findings of this research indicates that rising asset price do indeed have an impact on the capital share of GDP. In the first paper, we establish that in the US case a significant fraction of the declining labor share during the postwar period is due to so-called factorless income streams. Using data from the BEA, we show that depreciation has risen substantially on the aggregate level. We also decompose depreciation rates by sector and by asset class. The analysis reveals that a significant fraction of the depreciation share nowadays is due to the increasing importance of intangible assets in the economy, such as patents and other Intellectual Property. Conceptually, this raises a number of important questions. First, corporations might have an obvious incentive to overstate depreciation rates, given that consumption of capital is a cost of production and can therefore decrease a firm's tax liability. Second, intangible assets might not always have a fair market value, meaning that both the asset's market price and therefore also its capital consumption allowance might not always be determined. Third, there is a lot of evidence that firms engage in international tax arbitrage (Zucman, 2013; 2015). One way of doing this is by shifting as many intangible assets to tax-havens like Ireland, which can also lead to sizeable distortions in national GDP figures. While Irelands GDP has been revised substantially upwards in recent years, these income streams were not accruing to any domestic factor of production in the Irish economy. Instead, it was the result of foreign companies shifting intangible assets to the low-tax economy and earning the income stream in Ireland instead in order to benefit from the low tax rate. Consequently, these activities also had the side effect of leading to a substantial downward shift in the Irish wage share. The paper also examines a second imputed factor that has led to a decline in the aggregate wage share in the US. While the rent share of GDP has stayed fairly constant, imputed rents have increased from about 6% to almost 8% of GDP over the last few decades. Given that many advanced economies have experienced a similar boom in real estate prices, this phenomenon also seems to be quite global in nature. The research thus shows that a large fraction of the decline in the US labor share is indeed a result of capital becoming increasingly important in the production process, even if the mechanism is indirect and comes from imputed factors, which are depreciation as well as imputed rents. We also show some evidence that these trends have acted on the global level and therefore can be extrapolated from the US case, which we have examined in more detail. Both phenomena might ultimately be related to Larry Summers' theory of secular stagnation. The global decline in real interest rates has put upward pressure on asset prices, including housing, which ultimately will translate into higher imputed rents. Furthermore, rising asset prices might also boost depreciation shares.

From a policy point of view, the decline in the labor share, especially related to the house price boom, is obviously concerning because it also increases inequality. Homeowners tend to be the more affluent within society and capital, especially stock ownership, tends to be highly concentrated. Policy makers should aim to rein in the real estate boom that has taken place across advanced economies since the end of Bretton Woods, given that younger generations are increasingly priced out of the housing market. Furthermore, we have shown that the boom came hand in hand with a spectacular increase in private sector debt, mostly related to mortgages, in some countries exceeding one year's annual GDP. This has the potential to create dangerous boom and bust cycles a la Minsky, and should obviously be of concern for policy makers, given that financial crises are commonly associated with significant losses in output. Ultimately, the rise in house prices, especially in the large metropolitan areas, can only be addressed with rising supply and tighter credit standards. However, the latter option might also deny some people from participating in the housing market and should therefore be only used as a last resort in the case of a significant credit boom with relaxed lending standards that could also threaten the health of the economy.

In terms of capital consumption allowance, we find that is especially the increase in intangible assets that has translated to higher deprecation shares. Moreover, firms increasingly shift these intangible assets to low-tax jurisdictions as to benefit from a more favorable tax treatment. This behavior can only be addressed with international cooperation between countries, including the tax havens themselves. As this is rather unlikely to happen, major players like the US and the EU might have to coerce those countries in question in order to set up more equitable international tax laws.

The second paper uses long-run panel data and confirms the relationship between asset price booms and the capital share of GDP. This empirical finding is again related to the secular stagnation hypothesis, given that the long-term decline in real interest rates has simultaneously boosted asset prices across the globe. We have mentioned above that policy makers should be concerned about this symptom, since it increases inequality and potentially reduces financial stability at the same time.

We confirm the secular downward trend of real interest rates in our third paper. Our research also shows that national real interest rates seem to be highly dependent on global factors in today's world of globalized capital markets and financial mobility. This poses formidable challenges to monetary policy makers since it suggests that Central Banks have much less autonomy over short term interest rates than what is commonly assumed by neo-keynesian models. Our research can thus explain why many Central Banks have found it increasingly difficult to raise interest rates after the financial crisis. While several attempts have been made, such as by the ECB in 2011 and by the Riksbank in 2012, these Central Banks were quickly forced to resume course and lower rates again, given that the monetary tightening produced a significant economic slowdown. As those Central Banks quickly found themselves constrained by the zero-lower bound yet again, this supports the notion that international forces have pushed down rates globally and that policy makers might have lost autonomy to a large extent over the domestic rate of interest, as we will suggest in our third research paper.

Finally, the last paper discusses city growth in Sweden for a time period of two hundred years starting in 1810. While at first this topic does not seem to be related to the other papers in the thesis, one should recognize that increasing agglomeration effects in recent decades have significantly contributed to some of the ailments from which advanced economies have suffered in recent decades, such as the rise in inflation-adjusted house prices combined with increasing private sector debt and declining productivity growth.

The particularity of the Swedish rank-size distribution for cities might even have macroeconomic implications. First, Ellis and Andrews (2001) have shown within a theoretical model that countries with one clear primate cities are expected to have higher average national house prices. The rationale is that high house prices in the primate city will pull up the national average. The Jorda, Schularick, and Taylor Macrohistory database (2016a; 2016b) indeed confirms that inflation-adjusted house prices have increased rapidly in Sweden in recent years and that they tend to be quite high compared to other advanced economies. Second, a lot of empirical research has found that agglomeration effects are key for driving economic development (Moretti, 2012). Infrastructure, inputs, and a lot of other economic variables scale sublinearly with city size, which means that large cities can economize on inputs and infrastructure (Bettencourt et al., 2007). This has important implications for productivity. A lot of research has shown that larger cities are more productive (Glaeser, 2012). While Stockholm län produces almost a quarter of Swedish national GDP with just one fifth of the national population, the fact that the subsequent cities in Sweden are all smaller than implied by the Zipf's law could be of macroeconomic consequence. Hsieh et al. (2015) have estimated that US potential output could increase by as much as 10% if high-income states would have a much more elastic supply of housing. The increase in potential GDP would then result from people moving from low-productivity to high-productivity regions within the US. Similarly, Swedish potential output could increase by a few percentage points if housing supply in the large Swedish cities following the capital in the rank-size distribution, but also including Stockholm, was more elastic. In the 1960s, the Swedish government set up the "Miljonprogrammet", which was an ambitious housing policy that led to the building of about a million new dwellings countrywide over a time period of one decade. Some research suggests that housing investment has fallen behind in recent years. A similar program could be set up today, with a greater focus on the large three large agglomerations in Sweden, Stockholm, Gothenburg, and Malmö. While further research is warranted, it is extremely likely that Swedish potential GDP could increase by allowing for a more elastic housing response in the bigger Swedish cities, which would then also lift them towards their Zipf-consistent population estimate. Following the approach of Hsieh at el. (2015), one could therefore estimate the elasticity of GDP with respect to an increase in housing stock in the large Swedish cities.

From a policy point of view, addressing the rising house prices across advanced economies should therefore be very high on the list of priorities. Not only would an increase in housing supply in large metropolitan areas reduce inequality, but it also has the potential to increase aggregate productivity and therefore provide a cure to some of the problems related to secular stagnation.

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Paper I

ABSTRACT

It is well known that the labor share of income has fallen quite significantly in many countries in recent decades. A lot of research has focused in one way or the other on the decline of the bargaining power of workers, either being the result of the erosion of labor unions, global offshoring, a rise in corporate market power, or increasing financialization. We argue that most of these explanations seem to be insufficient to explain a large part of the fall of the labor share. Moreover, all these competing theories cannot be true in aggregate. We argue that net of imputations, factor shares have actually remained relatively constant in recent decades. In the US, there are two simple factors alone that can explain most of the decline in the US labor share, namely a significant increase in consumption allowance of fixed capital (depreciation) as well as the rise in imputed rents. While both of these items are included in GDP, they are technically not an income stream to any factor of production. The rise in imputed rents has increased significantly in recent decades as both the size as well as the quality of housing services has increased, with obvious implications for house prices. Consequently, one can observe a significant increase in the rental income share of GDP with most of the increase in the US being attributed to owner-occupied housing. While we do find a marked decrease in the labor share in certain industries, again most of the decline can be explained by the increase in depreciation rates as a share of gross value added, which seems to be a crucial but also one of the most neglected macroeconomic trends in the literature. We also provide tentative answers as to why deprecation rates have increased in aggregate. More specifically, in the case of the US economy but also internationally, a significant share of the increase is due to the rise of intangible capital, such as patents.

Key words:
Labor share; depreciation; imputed rents; intangible assets

The decline of the US labor share, depreciation, and imputed housing costs

1. Introduction:

While some of the more simple macroeconomic models still posit that factor shares are relatively constant in the long-run, most economic historians would give such an assertion a mere shrug. It is now well known that income shares have fluctuated quite wildly over the last century for the countries for which researchers have gathered data (Bengtsson and Waldenström, 2018). One of the more well-known patterns is the U-shaped curve for the capital share, which historically has been quite high in most countries both at the beginning as well as at the end of the 20th century (Bengtsson and Waldenström, 2018). This obviously also implies that the labor share of GDP was relatively high in the aftermath of World War II. In his original work "Capital in the 21st century", Piketty (2014) asserts that the large macroeconomic shocks of the early 20th century, the two World Wars and the Great Depression, led to an enormous destruction of capital around the world, which had obvious implications for capital income. As such, the immediate postwar period was rather favoring labor on net and thus being characterized by an unusually low capital share of GDP (Piketty, 2014).

In this paper, we examine the decline of the labor share in the US by digging deeper into the National Income and Product Accounts (NIPA). While a lot of recent research has tried to explain the global decline in the labor share using various statistical techniques, we will show that such attempts might have been ultimately misguided and also led to conclusions that are hard to reconcile with our study. Many papers have attributed the fall in the labor share to one single factor that can supposedly account for the largest part of the decline. As such, many culprits have been identified, mostly focusing on the decline in the bargaining power of workers. In no particular order, economists have singled out the following variables as being the one important determinant of the falling labor share: the erosion of labor unions (Fichtenbaum, 2011), globalization and offshoring (Elsby et al., 2013), increasing financialization (Stockhammer, 2013) and rising asset prices, especially housing (La Cava, 2016). Skill-biased technological change (Jaumette and Tytell, 2007), and increasing market power and rising markups in the corporate sector (Autor et al., 2017), have also been emphasized as possible factors.

While there might obviously be some truth to all these theories, they obviously cannot all account for the lion's share of the decline in the labor share at the same time. Furthermore, in what follows, we assert that most of the decline in the labor share can actually explained by two single factors alone, which are the gradual rise in capital consumption allowance (depreciation) as a share of GDP, followed by the gradual rise in imputed rents. Taken together, those two variables can account for almost the entirety of the decline in the gross labor share, meaning that all other factors mentioned above might be of not that much importance after all. This obviously begs the question whether many of these studies have simply fallen into the econometrics trap where statistical significance might simply the result of spurios regressions in form or the other.

The gradual rise in economy-wide depreciation, increasing from about 8% of GDP in the 1950s to about 14% as of today, seems to us one of the most consequential macroeconomic trends in recent decades, which at the same time has not received the necessary attention it deserves. Bridgman (2018) and Karabarbounis and Neiman (2014) are the notable exception, who discuss the importance of distinguishing gross vs. net labor shares. As depreciation cannot be measured directly but is simply estimated, this begs the question whether part of the increase is simply a statistical illusion so to speak, being the cause of measurement errors and the like, or whether the increase is a "real" phenomenon. We will see later on that there might be some merit to the argument that depreciation of intellectual property is overstated, given firms' incentive to reduce their total tax burden. However, it also seems plausible that technological change in recent decades has altered the structure of production in such a way that physical capital becomes obsolete at a faster pace. This is especially true for ICT technologies, which seem to have a much shorter lifespan on aggregate (Oulton, 2002). The rise in depreciation rates also implies that we might have slightly overestimated real GDP growth, since replacing obsolete capital counts as spending but obviously does little too improve living standards.

The most important contribution of this paper is to decompose changes in the gross labor share by industry and to calculate depreciation shares by industry and asset type. The data shows that while depreciation of dependent structures and industrial equipment has risen slightly, especially in the aftermath of the Reagan tax cuts that allowed for a much more generous deductions of capital consumption (the so-called Accelerated Cost Recovery System, short ACRS), most of the increase can actually be accounted for by Intellectual Property Products (IPP). The rise of intangible assets as a result of technological and structurual change, accompanied by changes in the tax code, has allowed firms to deduct significant amounts against their current tax base, thus improving overall profitability. Naturally, this begs the question whether the increase in depreciation as a share of gross value added is a real phenomonon with actual capital wearing down at a faster pace, or whether it is simply the result of firms' clever behavior to exploit tax loopholes to the fullest.

The second factor that has led to a depression of the labor share is the rise in the value of rental income, more specifically imputed rents of owner-occupied housing. While this latter item is included in the GDP calculations, it should be noted that imputed rents do not technically represent any actual income streams whatsoever. Regardless, imputed rents are a measure that calculates the housing services that a homeowner derives from his own dwelling, thus supposedly estimating the rent that he would pay to himself. As the quality and size of owner-occupied housing increases over time, imputed rents must also rise, given that people's willingness to spend on housing services in general increases. Furthermore, a general rise in real house prices, simply being the result of shifts in demand and supply, will ultimately drive up rents and thus also imputed rents, given that the price of owner-occupied housing rises too. Arguably, this is exactly what has happened in recent decades. Housing demand in many advanced economies has increased dramatically, especially in the large agglomerations, but supply has remained relatively static in the short to medium run, thus pushing up real house prices (Turner, 2017). As such, imputed rents in the US have risen from about 6% of GDP in the 1950s to almost 8% of GDP as of today.

We will see below that the gradual rise in economy-wide depreciation as well as the increase in imputed rents can account for the largest fraction of the fall in the gross labor share in recent decades, thus making all other theories somewhat questionable. As net labor shares have remained much more stable than gross labor shares, this begs the question whether the entire debate about factor incomes has been framed the wrong way. Moreover, most of the rise in depreciation seems to be related to Intellectual Property, which as an asset class has a much faster depreciation rate than more conventional types of capital.

2. Literature review:

The academic literature on factor shares has flourished in recent years and several factors have been identified as being one or even the single one driver of the declining labor share of GDP. Many research papers, such as Stockhammer (2013) or Probst (2018) for example, have used cross-country regressions to identify the main variable(s) that is (are) causing the factor shares to vary over time. Usually, such a regression takes the following form:

$$(1) \quad LS_{i,t} = \beta_0 + \beta_1 * x_{i,t} + Z_{i,t} * \beta_2 + d_t + \varepsilon_{i,t}$$

where $LS_{i,t}$ is the labor share of country i at time t, $x_{i,t}$ is the main variable of interest that supposedly captures a large part of the variation in factor shares, and $Z_{i,t}$ is a vector of relevant control variables. Commonly, country fixed effects and time fixed effects are included to control for country-specific factors as well as for yearly unobserved macroeconomic shocks.

In such a way, many papers have supposedly identified the key variable(s) of interest that caused the labor share to trend downward in recent decades. Using a panel data approach, Fichtenbaum (2011) has emphasized the erosion of labor unions in many countries as one of the main factors in causing the decline of the labor share. Stockhammer (2013) has identified increasing financialization, meaning the growing importance of the financial sector in the economy, as one of the key causal mechanism. Elsby et al. (2013), on the other hand, assert that offshoring has played an important role. Jaumette and Tytell (2007) suggest that capital-biased technological change has been a contributing factor. Finally, Karabarbounis and Neiman (2013) assert that most of the fall in gross labor shares can be attributed to the relative decline in the price of investment goods whereas Grossman et al. (2017) suggest a causal mechanism between the recent global decline in labor productivity and the labor share.

Many of the aforementioned papers have in common that they use some kind of panel regression to identify the underlying factors that have caused the labor share to decline in recent years. However, in the words of Angrist and Pischke (2008): "Good econometrics cannot save a shaky research agenda, but the promiscuous use of fancy econometric techniques sometimes brings down a good one." While there might be some truth to all the theories mentioned above, all of them can only be true in aggregate if they capture some common underlying effect. Many of the aforementioned factors, for example, might have in one way or the other an adverse impact on the bargaining power of labor, and thereby negatively affecting the wage share in that way (Stockhammer, 2013).

More recently, a second strand of literature has identified the rise in markups and monopoly power as one of the key factors. Some papers, such as Barkai (2016), have argued that actually both the labor share as well as the capital share have declined in recent decades as the result of rising monopoly rents. Grenestam and Probst (2014) have estimated markups for U.S. industries based on an approach that was first proposed by Hall (1988), and later revised by Hylleberg and Jorgensen (1998).

Autor et al. (2017), on the other hand, have suggested that the decline in the labor share is the result of rising superstar firms in certain industries with a suffcient degree of market power. As those firms are more capital intensive, they tend to employ less labor on aggregate. However, estimating markups is a tricky business and the identifying assumptions are relatively strong. First, the estimation rests upon measuring the rental rate of capital, which is a rather elusive concept and difficult to measure. Second, one of the common identifying assumptions is that of a constant depreciation rate (Hylleberg and Jorgensen, 1998). However, as we will show in the paper, depreciation rates have been on a secular rising trend across industries over the last few decades. Third, the paper by Barkai (2016) uses an elasticity of substitution between capital and labor that ranges from 0.4 to 0.6 in the parameterization exercise to calculate to what extent the falling factor shares can be attributed to rising markups. While microeconomic estimates seem to confirm such an assumption (Lawrence, 2015), macroeconomic studies actually find some conflicting evidence. More specifically, Piketty (2014) asserts that the gross elasticity of substitution ε on the macro level is actually larger than one. Similarly, Karabarbounis and Neiman (2013) find a value of about 1.25 for ε. Given the strong identifying assumption that are at the core of estimating markups, there remains some doubt as to whether these estimates are actually correct.

Some authors have also rightly emphasized that there is a difference between the gross labor share and the net labor share, with the latter excluding economy-wide depreciation. While Karabarbounis and Neiman (2014) suggest that gross and net labor shares generally move in the same direction, there are some important cross-country differences. Cho et al.

(2017), on the other hand, suggest that in the case of Korea a substantial part of the decline in gross labor shares is the result of rising depreciation. Moreover, this decline is especially pronounced during times of rising asset prices, and in particular land and house price bubbles (Cho et al., 2017). This is in accordance with some other studies that have suggested that the decline in the labor share is simply the result of rising asset prices (Gonzalez and Trivin, 2017; Probst, 2018). Koh et al. (2016), for example, have identified the increase in the return from Intellectual Property (IP), such as patents, as one of the factors that decrease the labor share. La Cava (2016) has shown that the rent share of GDP in the US has increased quite significantly in recent decades, surely following the increase in real house prices, with imputed rents being the main culprit. Probst (2018) shows that the capital share is highly correlated with stock market booms in the short to medium run. Last but not least, Bridgman (2018) finds that the net labor share adjusted for depreciation and production taxes, has actually not declined in the US case, meaning that the international focus on gross shares might give a very misleading picture.

Studies like Gonzalez and Trivin (2017) and Cho et al. (2017) have thus confirmed the increasing importance of rising asset prices globally and the associated increase in income streams. The former emphasize the global increase in Tobin's Q, leading to higher equity returns in general and also depressing the wage share (Gonzalez and Trivin, 2017). Cho et al. (2017), on the other hand, find that the labor share net of depreciation and excluding taxes and subsidies has remained relatively steady from an income perspective while it is especially during times of land and housing bubbles that the gross labor share decreases.

Finally, a new strand of literature has argued that a significant share of the decline in the gross labor share is due to the so-called factorless income streams (Karabarbounis and Neiman, 2018). Research done by Zucman (2015) and others (Bessen, 2016) has confirmed the rise of intangible assets in today's economy. Moreover, companies increasingly shift intangibles around the world to low-tax havens like Ireland, thus further distorting the picture, given that both GDP and the gross capital share increase without these activities having a similar impact on net domestic income (Damgaard and Elkjaer, 2017).

Following this line of reasoning, we will adress in this paper the role of rising depreciation as well as the increasing importance of imputed rents, both of which are part of GDP but do not represent actual income streams to any factor of production. Instead of running yet another regression of the labor share against some outcome variable, we will dig deeper into the national accounts and decompose the fall of the labor share by sector. Our results indicate that the fall in the gross labor share can mostly be accounted for by the increase in depreciation rates across sectors, with the rise of intangible capital explaining a significant share of the rise in aggregate depreciation rates.

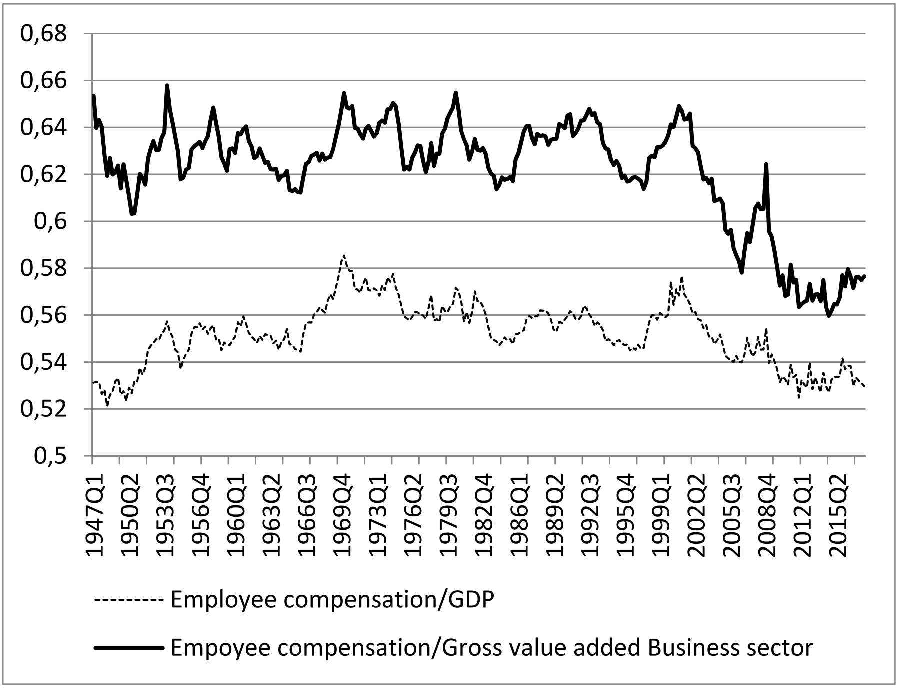

Figure 1:
Gross labor share of GDP and gross labor share of the business sector
Source: BEA

3. Measuring GDP and factor shares

There are generally several different approaches on how to measure GDP. Besides the production approach, we also have the expenditure approach and the income approach. On the aggregate level, the sum of all expenditures should of course be equal to the sum of all incomes in the economy. In reality, however, these two approaches might yield slightly different results because of statistical discrepancies. In what follows, we will focus on the second approach where GDP is simply the sum of all income streams, including some adjustments being made for taxes and depreciation:

$$(2) \quad \text{GDP} = \text{Compensation of employees} + \text{Rent} + \text{Interest payments and miscellaneous investment income} + \text{Proprietors' income} + \text{Corporate Profits} + \text{Indirect business taxes} + \text{Depreciation} + \text{Net foreign factor income}$$

GDP is thus the sum of employee compensation, rental income, interest payments and investment income, proprietors' income and corporate profits. We must also add indirect business taxes, which are part of total expenditures, as well as depreciation of fixed assets, which is considered to be a cost to production. Finally, we must add net factor income from abroad. Employee compensation does not only include wages and salaries, but also supplements to wages, such as housing allowances, contributions to employee pension funds and such (Giandrea and Sprague, 2017).

Figure 1 displays total employee compensation as a share of total GDP and as a share of gross value added of the corporate sector. One can see that the gross labor share of GDP has declined by about four percentage points from a high of 0.57 to a low of 0.53 over the last two decades. While the current value is quite low from an historic point of view, one should note that it is not noticeably lower than during the immediate postwar period. However, employee compensation as a share of gross value added for the corporate sector has declined even more strongly, reaching an absolute low of 0.57 in recent years after staying relatively constant in the narrow range of 0.62 to 0.66 for almost five decades after World War II. Employee compensation as a share of gross value added for the corporate sector has thus declined by almost six percentage points since the eary 2000s.

4. Adjustment for the self-employed

One of the most significant trends in the postwar period has been the relative decline of proprietors' income, which has decreased from about 15% of GDP in the immediate postwar period to about 7% of GDP in the late 1970s and has subsequently stayed close to that value. The decline in proprietors' income has come hand in hand with a steady dowwnward trend in the self-employment rate, from a high of more than 16% in 1947 to about 8% in the late 1970s. It subsequently remained relatively constant, only to decline an additional two percentage points over the last couple of decades to reach a low of 6% in recent years (see figure 1 in the appendix). A significant part of the reduction of proprietors' income has been the result of the continuous and steady decline of farm proprietors' income, which accounted for almost 45% of total proprietors' income in 1948 and was reduced to just a little more than 2% in recent years.

While part of proprietors’ income can be attributed to capital, a significant share of it is wage income, especially considering the fact that self-employment tends to be much higher in labor-intensive industries like the service sector. Unfortunately, proprietorships only report total income and therefore one can only estimate the share that we should attribute to labor. Two distinct methods have been suggested to estimate proprietors’ wage income: the capital return approach and the labor income approach (Kravis, 1959). The first approach assumes that proprietors' return to capital is the same as the ones of corporations and proprietors’ wage income is then simply the residual. The obvious flaw in this line of reasoning is to assume that capital returns are equalized across sectors. Even with the relatively strict assumption of efficient markets, proprietors' return could still be different than capital returns in the corporate sector if proprietors' capital has a different risk profile. The second method estimates proprietors' wage income more directly by assuming that proprietors have the same hourly wage as employees in the corporate sector (Giandrea and Sprague, 2017). The obvious flaw in the second method is to assume that proprietors and employees have the same hourly wage income. A priori, this will not be the case if there are some innate differences concerning their skills and the level of human capital between the two groups.

We have estimated the proprietors’ total labor income from 1948 to 2016 by using the BEA's data on the number of self-employed in each sector. This data is available for 10 sectors prior to 1998 and 14 sectors thereafter, excluding proprietors' farm income for the entire period. This omission is relatively inconsequential as proprietors' farm income accounted for a mere 2% of total as of 2016. We calculate total proprietors' wage income by assuming that they have the same annual wage as full-time employees in the same sector of the economy. While we are aware that this is a very strong assumption, our method seems to be a relatively good first order approximation for proprietors' total wage income, given the data limitations at hand. Some research has noted that proprietors' tend to have a higher mean age and most likely also a higher skill level than a regular employee in the same sector (Georgellis and Howard, 2000; Blanchflower, 2000), meaning that our estimation for proprietors’ wage income might be biased downwards.

However, since we are more interested in the direction of change over time, this ultimately is only a problem if the direction of the bias is non-stationary and changes significantly over time.

Figure 2:
Proprietors' wage share as a share of total proprietors' income and proprietors' wage share as a share of total GDP. Source: BEA

Figure 2 displays proprietors' wage share, excluding farms, calculated as outlined above. While there is a significant downward trend in recent decades, proprietors' wage share is at about 55% as of today, which corresponds roughly to the value it assumed in the early 1970s. The huge increase in the proprietors' wage share within just a few years to more than 80% in the early 1980s as well as the subsequent dramatic decline must be regarded as an outlier in the data. There is a case to be made that this was due to the Economic Recovery Tax Act of 1981 under Ronald Reagan as proprietors' total income as a share of GDP declined by a significant amount just after the tax law was passed.

In terms of proprietors' total wage income, one can see that it declined from about 4% of GDP in the 1980s to just about 3% of GDP in recent years. Adjusting for the self-employed, there has thus been an additional one percentage point decline in the economy-wide gross labor share, which is the result of two factors. First, a compositional effect as the share of self-employed has been falling over time in recent decades. Second, a within effect as the result of a falling labor share for the self-employed, assuming that our imputation for proprietors' wage income is not severely biased. However, it should be noted that this adjustment for the self-employed can only account for a minor fraction of the total decline in the economy-wide US gross labor share in recent decades.

However, when considering this kind of data, it should be noted that one must proceed with some caution. Proprietors' income might be measured inaccurately as a result of several factors, such as underreporting of income, tax evasions, and illegal activities. For that reason, the BEA adjusts the annual income of sole proprietorships accordingly as to account for such discrepancies. In 2001, for example, the BEA made an adjustment of about 300 billion US dollars compared to the Census Bureau's Current Population Survey, meaning that the proprietors' income misreporting adjustment accounted for about 40% of proprietors' total income (Ruser et al., 2001). However, the gap should not be used as a gauge for illegal activity and non-compliance since the misreporting adjustment also includes the legal nonfiling of income (Ledbetter, 2004).

While there is the obvious concern that the adjustments for misreporting are incorrect and biased in one way or the other, for the purpose of our study we simply note that the proprietors' total wage share is relatively miniscule as a share of total GDP. Therefore, any mismeasurment issues cannot significantly affect and alter our conclusions about the change of the total wage share.

5. Sectoral decomposition

In what follows, we will focus on the labor share in private industries. The aggregate labor share can change as a result of two distinct factors. First, there can be a so-called shift factor, which is simply the result of a sectors' relative contribution to total output changing over time. This will also induce changes in the aggregate functional distribution of income, since some sectors are much less labor-intensive than others. Second, the aggregate labor share can fall as a result of the within-industry effect where labor shares are changing in general across sectors, either as a result of technological change, higher markups, or other factors that somehow affect the production function. Following Giandrea and Sprague (2017), we use a simple decomposition exercise based on the following equation to determine to what extent the total decline is due to the within-effect vs. the structural effect. The change in the weighted labor share of industry i is then simply the sum of the following three terms: The within-industry effect, the structural effect resulting from changes in the sectorial composition of output, and the product of the two.

(3) $$Change\ in\ weighted\ labor\ share$$
$$= \sum_i [(LS_{i,end} - LS_{i,initial}) * W_{i,initial} + (W_{i,end} - W_{i,initial}) * LS_{i,initial} + (LS_{i,end} - LS_{i,initial}) * (W_{i,end} - W_{i,initial})$$

where LS and W stand for the labor share and the output share, respectively. The subscripts denote the particular sector i as well as the corresponding time period.

From the National Income and Product Accounts (NIPA), we have annual data for 14 different sectors as well as the government from 1947 to 2016. We split our sample into three different time period: from 1947 to 1970, from 1970 to 1986, and from 1987 to 2016. While these years were chosen somewhat randomly, we use the year 1986 because it corresponds to the date when the BEA's industry classification was changed after 1987. This was mainly the result of new industries emerging as a result of technological change, such as the emergence of the Information and Communication Technologies (ICT) sector, as well as the creation of many service sector jobs that did not exist previously. Consequently, for some sectors, especially those that are related to services, the numbers between 1986 and 1987 are not strictly comparable, since additional industries were added to the national accounts that did not exist in the BEA's dataset as separate entries previously. The year 1970 was chosen somewhat arbitrary, but at the same time it is a natural cutoff point for the postwar period because it corresponds roughly to the midway point in between 1947 and 1986. Furthermore, it was in the early 1970s that the gross labor share reached its peak. However, using a slightly different date than 1970 does not significantly alter our analysis.

Table 1 in the appendix displays the labor share as well as the changes in the labor share while table 2 displays the corresponding output shares and the changes in output shares for all the sectors in our analysis. One can see that the gross labor share for private industries rose signficantly in the immediate postwar period from 1947 to 1970 with an increase of more than five percentage points from about 53.2 to 59.4%. Subsequently, the gross labor share declined by about 1.8 percentage points from 1970 to 1986 while in the last period from 1987 to 2016 it declined by an additional 2.3 percentage points.

In table 3 in the appendix, we have calculated the compositional effect for all the sectors for our three time periods in question. Most of the increase in the aggregate gross labor share in the first period was the result of the within-effect, given that most sectors displayed an increase in the gross labor share. The structural effect, on the other hand, was actually working against the increase in the labor share, since the sectoral composition of output changed towards less labor-intensive industries during that time period.

In the second period from 1970 to 1986, the average within-effect across industries is reduced virtually to zero, meaning that changes in the gross labor share across different sectors were basically offsetting each other on aggregate. However, one can observe a marked decline in the structural effect, implying that the entire decline in the aggegrate gross labor share in this period was due to the compositional effects, with low labor share sectors gaining in importance by increasing their relative output share in the economy.

In the last period from 1987 onwards, one can see a reversal as the compositional effect is now basically reduced to zero whereas the within-effect increases in importance again. The latter can now explain almost the entirety of the decline in the aggregate gross labor share. Consequently, the decline of the gross labor share since the late 1980s has been almost exclusisvely the result of a declining labor share within industries, rather than being the result of changes in the sectorial composition of output.

6. The rise of depreciation as a share of total gross value added

In the case of the US, changes in the tax system over time also had a sizeable impact on how depreciation costs are calculated at the firm level and for individuals, and it seems that this also had meaningful consequences for macroeconomic aggregates. During the Reagan administration, Congress passed the Accelerated Cost Recovery System (ACRS) as part of the Economic Recovery Tax Act. The tax overhaul introduced major changes to how firms can deduct depreciation expenses. The aim of the tax change was to allow individuals and businesses to write off capitalized assets in an accelerated manner, which would thus increase the tax deduction for property and free up cash flow. For that purpuse, all property was divided into different into asset classes with specified useful lives, ranging from three to 19 years, depending on the underlying asset in question (IRS, 2012). While proponents argued that these measures would spur business investment, there was some concern that it would actually spur consumption instead. Furthermore, the ACRS increased the danger of treating depreciation merely as an accounting convention instead of a true economic cost. Under the ACRS, companies were allowed to take ultra rapid depreciation on capital intensive assets. By reducing corporate tax bills, the tax act thus led to a disparity between cash flows and reported earnings. The favorable tax treatment of capitalized assets thus also had the unintended consequence of leading to a large number of hostile takeovers by freeing up cash reserves for large corporations (Smirlock et al., 1986; Nelson, 1987).

Responding to criticizm on the previous bill, Congress passed a new and modified tax law in 1986, the Modified Accelerated Cost Recovery System (MACRS), with the main difference being that MACRS uses a longer receovery period for residential and non-residential real estate and thus decreases the granted annual depreciation deductions. Under the new system, the capitalized cost of property is recovered by annual deductions for depreciation, which is calculated either as declining balance switching to straight line midpoint or straight line depreciation throughout. Under declining balance, more depreciation expenses occur upfront as a specified percent of the asset's original cost is recovered each year whereas under straight line depreciation the same fixed amount is deducted over the asset's lifetime using the following formula:

$$(4) \quad Annual\ depreciation\ expense = \frac{Cost\ of\ fixed\ asset - salvage\ value}{Useful\ life\ of\ asset\ in\ years}$$

With the MACRS, assets were classified into different asset categories and the useful life was specified for each category (IRS, 2012). The law still allowed for relatively generous depreciation deductions as the useful life of assets was set relatively low[1], meaning that companies could recover the cost of their investment more quickly than before the Reagan tax laws came into effect[2]. As depreciation of capital or capital consumption allowance is a counted as a cost of production, it is part of gross value added and therefore also GDP. In business accounting, companies usually measure depreciation at historical cost. A company's asset, for example, is thus carried on the balance sheet at its acquisition cost. Commonly, depreciation costs then occur

[1] Consult table 5 in the appendix for an overview of the specified useful life by asset class.

[2] Consult Appendix B for specifics on the ACRS and MACRS.

annualy over the asset's calculated life time using straght-line depreciation[3]. The BEA, on the other hand, measures depreciation of private fixed assets at current cost in the NIPA, meaning that assets are constantly re-evaluated based on their fair market value.

The rise of depreciation as a share of gross value added also rises an important conceptual questions, especially since most of the increase can be attributed to IP products. Firms obviously have an incentive to overstate depreciation costs for the national tax authorities, the Internal Revenue Service (IRS) in the US. There is an obvious advantage for firms to frontload depreciation expenses as much as possible as to improve current cash flows. Furthermore, firms also have an incentive to overstate depreciation expenses to improve profitability by deducting these costs against current profits, which then reduces the overall taxable profit base. This is especially true for intangible products, like patents and brand values, for which it might be relatively hard to assess a true and fair market value. Consequently, firms might have a tendency to overstate the value of intangible products for tax purposes in order to be able to deduct as much depreciation expenses as possible.

The BEA's data also allows us to decompose both economy-wide and sectorial depreciation by asset type. More specifically, we obtain depreciation for all sectors for three different types of assets seperately, which are equipment, dependent structures, and Intellectual Property (IP). The data shows that depreciation of private fixed assets measured at current cost increased from just 8% of gross value added in private industries in 1947 to more than 14% in 2016 (see table 4 in the appendix). Depreciation of equipment increased from about 3.7% of gross value added in private industries in 1947 to reach a peak of about 6.5% in 1987. However, it

[3] One alternative way to calculate depreciation historic cost instead of at current cost. The difference is of particular importance during times of rising prices, especially for assets that are being hold on the balance sheet for a lengthy period. In balance sheets prepared on a historical cost basis, assets may be entered well below current fair market value during times of rising input and asset prices. The drawback of current cost, on the other hand, is that it might be difficult to establish a fair market value over time for some assets, especially if there is no liquid market for the sale of the particular asset in question (this could be especially the case for intangibles). So while it might be preferable mark asset prices to market on a continuous basis, this is not always be manageable in practice. In the GDP statistics, depreciation (or capital consumption allowance) of private fixed assets is commonly estimated at current cost and accounts for more than 14% of GDP as of 2016 in the US. At historic cost, however, depreciation of pivate fixed assets accounts for only 10% of GDP. The two different methodologies thus yield strikingly different results even on the macroeconomic level.

subsequently declined again to about 5.4% of GDP in 2016. Depreciation of dependent structures only increased modestly between 1947 and 1987 from about 3.8% to 4.8%. It subsequently increased further to about 5.3% of total gross value added as of 2016. Finally, and most importantly, depreciation of Intellectual Property is almost non-existent in 1947 and only accounts for about 1.6% of private industries' gross value added. While it only rose modestly thereafter to reach 2.3% in 1987, this category shows the most marked most marked increase in recent decades. As of 2017, depreciation of IP accounts for more than 4% of gross value added. According to the BEA's data, a substantial part of the increase in depreciation in private industries therefore comes from IP alone, closely followed by dependent structures, whereas the depreciation share of industrial equipment has actually declined post 1987.

When breaking down the data by sector, one can see that depreciation as a share of gross value added has increased significantly across most sectors in the US economy. The decline in the labor share has been the most significant in the manufacturing sector and in utilties, more than 17 and 11 percentage points, respectively, between 1987 and 2016. This was closely followed by transportation and warehousing (minus ten percentage points), and retail trade and wholesale trade, each experiencing a decline of about seven percentage points over the same time period. It is especially in manufacturing and utilities where one can observe a quite significant increase in the depreciation share of gross value added. In between 1987 and 2016, depreciation increased by about six percentage points in manufacturing and 5.3 percentage points for utilities, implying that the increase can account for about 35% and almost 50% of the decline in the labor share of gross value added in those two sectors, respectively. The largest increase in the depreciation rate can be observed in the primary sector with an increase from about 16% to more than 27% of gross value added in between 1987 and 2016 while the labor share only declined by three percentage points over the same time period. On average, the depreciation rate in private industries has increased by about 2.5% and 1.2%, respectively, in between 1970 and 1987 and 1987 and 2016. As the gross labor share has fallen by 1.8% and 2.3%, respectively, one can see that rising depreciation alone can explain a significant amount of the decline. Unsurprisingly, the correlation coefficient between changes in the gross labor share and changes in the depreciation share is -0.26 for the 15 sectors under consideration during the last time period. All the evidence thus seems to suggest that even within sectors the rise in depreciation can explain a substantial part of the deline in the labor share of gross value added.

7. The rise in IP and IP depreciation

As shown in table 4.4 in the appendix, a significant part of the increase in economy-wide depreciation can be attributed to IP alone. While the depreciation rate for equipment in private industries has increased from about 2.6% of gross value added in 1947 to 4.7% of gross value added in 1987, there has been no significant change since the late 1980s. Similarly, deprecation rates for dependent structures in private industries have increased from 1.6% in 1947 to about 2.3% of gross value added in 1987. Subsequently, there was an additional increase of only half a percentage point until 2016. By far the biggest increase in depreciation can be observed in the category of Intellectual Property, which was virtually non-existent in the late 1940s, since it accounted for less than 0.5% of gross value added. IP depreciation has continuously increased over the last few decades and now accounts for about 3.5% of gross value added. The economy-wide increase in deprecation rates is thus almost entirely due to the increase in IP depreciation, with dependent structures coming in as a distant second factor.

Two sectors specifically, manufacturing as well as professional and business services, are accounting for a significant share of IP capital. Moreover, both sectors together also repressent roughly one quarter of total gross value added of the private sector. From 1986 to 2016, depreciation of IP capital increased from less than 5% to more than 10% of total gross value added in manufacturing whereas for professional and business services one can observe an increase from about 2.5% to 5% over the same time period.

Economy-wide depreciation can increase as a result of two factors, assuming that the deprecation rate of similar types of capital remains constant. First, an increase in the capital to GDP ratio, the process of capital deepening, would also lead to an increase in the depreciation share even with a constant depreciation rate. Second, there can be a compositional effect if firms alter their production and start to employ different types of capital that depreciate at a faster rate. The BEA calculates the net stock of capital for different asset types for the entire economy. Assets can be either valued at hsitorical cost or current cost. While under the historical cost method assets are carried forward on the balance sheet based on the cost of acquisition net of depreciation, the current cost method might be preferable because assets are recorded based on fair market value, again adjusted for depreciation, which should lead to a fairer assessment of the true market value for the sectorial balance sheets.

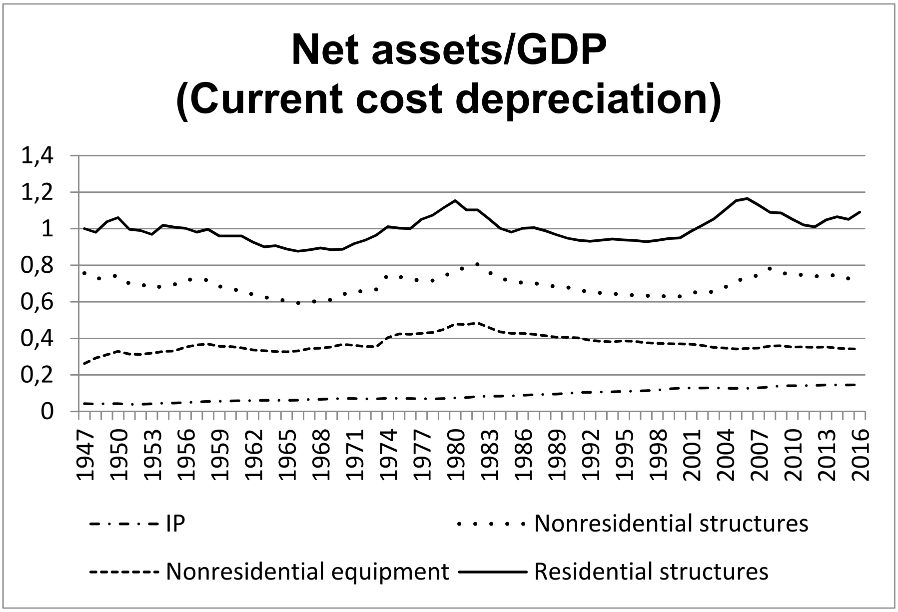

Figure 3:
Stock of net assets divided by GDP (measured at current cost) Source: BEA

The BEA's data reveals that there has been no no significant capital deepening in recent decades. The net capital to GDP ratio, both measured at current cost as well as at historic cost, has increased by about 15% since the late 1980s whereas the depreciation share of GDP has increased by a more significant amount. When it comes to residential and non-residential structures, one can observe a quite significant divergence in certain periods between the current cost and the historic cost method. This is due to the fact that residential structures have at times observed a significant increase in their value, such as during the hosuing boom of the early 2000s. Such a price appreciation consequently drives a wedge between the two methods since increases in market value are recorded at current cost, but not at historic cost. This implies that a substantial part of the capital deepening, especially with respect to residential structures, has simply occurred as the result of higher valuations rather than actual increases in physical quantities relative to trend value. The most significant change has occurred in the so-called modern sector of the economy. This would be the ICT sector as well the increasing usage of IP in other sectors, such as manufacturing, for example. Figure 3 above displays how IP capital has increased from a mere 4% of GDP in 1947, measured at current cost, to more than 14% of GDP as of today.

The BEA's data also contains the current cost mean age of private fixed assets across asset types. Unsurprisingly, residential structures have the highest average age with an of about 30 years at the end of 2016, up from about 25 years a couple of decades ago, while non-residential structures have an average age of a little more than 20 years. When it comes to non-residential equipment, the average age is just about seven years. Within that asset class, industrial equipment and transportation equipment have a relatively high average age of about seven and ten years, respectively. Unsurprisingly, computers and communication equipment are more modern technologies and have a very low average age of not much more than two and five years, respectively. The asset class with the lowest average age in general are Intellectual Property Products with an average age of just a little more than four years. Within that category, it is especially software that pulls down the mean with an average age of just about two years whereas research and development in the manufacturing sector has an average life of about five years.

Depreciation rates for ICT equipment and Intellectual Property Products are thus very high across the board, with IPP capital reaching a depreciation rate of more than 20% as of today (Koh et al., 2016). As capital intensity in the economy increases in terms of intangible products and other asset classes with low useful lifetimes like computer equipment and software, one can expect a general increase in economy-wide depreciation rates as a share of gross value added, which is exactly what we have observed in recent years across sectors.

8. The increase in imputed rents

Besides rising depreciation rates, there is another item in the national accounts that has increased significantly as a share of GDP in recent years, which is housing services. Figure 4 below displays the rental income and the imputed rent for owner-occupied housing units. One can see that while the former has remained relatively stable over time, there has been a continuous upward trend in imputed rents in recent decades, increasing from less than 6% of GDP in 1947 to more than 8% of GDP as of 2016. The rental income of owner-occupied housing is calculated as the imputed net income of the owner, that is the imputed output of housing services minus all costs, which includes depreciation, maintenance and repairs, and mortgage payments. Estimates of space rent is calculated as the number of owner-occupied housing units times the average rental value, which is estimated and benchmarked against data from the decennial Census of Population and Housing and rental values from the Census Bureau's decennial Residential Finance Survey. The BEA's method to calculate imputed rents is thus based on the rental equivalence method, which assumes that an owner-occupied dwelling yields the same rent as an actual rental unit of same size, age, quality, location, etc. Of course, this method presumes the existence of a well-functioning rental market, which is not always a given.

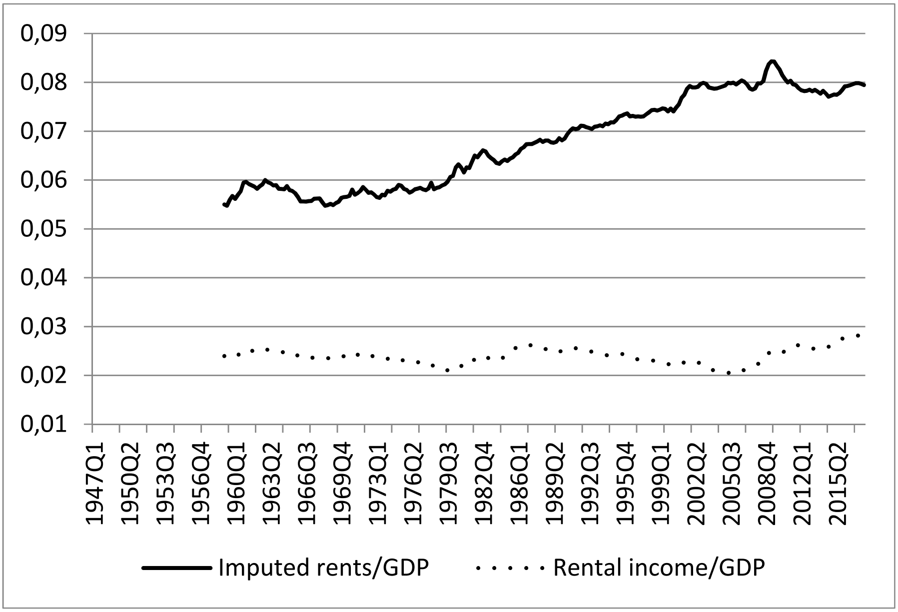

Figure 4:
Imputed rents and rental income as a share of GDP. Source: BEA

Imputed rents can thus increase as a result of several factors. First, an increase in home ownership rates would obviously lead to a larger imputed rent share while at the same time also decreasing the share of income obtained from rental units. Second, an increase in the quality and size of the owner-occupied housing stock increases the output of housing services and therefore also pushes up imputed rents. Third, a general increase in the value of housing units ultimately translates into higher rents and also higher imputed rents. Finally, a decline in the cost to owners, might that be depreciation rates and maintenance costs of residential structures, or mortgage payments, would also translate into higher imputed rents.

While the housing boom of the early 2000s in the US was associated with a marked increase in home ownership rates of more than three percentage points, the subsequent bust and long-lasting economic depression pushed those ownership rates back down to its initial rate of about 63% (see figure 2 in the appendix). The recent rise in imputed rents can thus not be explained by a higher home ownership rate alone. More recently, La Cava (2016) has pointed out that a significant part of the increase can mostly be attributed to two factors, which are a higher value of the existing housing stock and lower interest rates, which have pushed down mortgage payments.

Data from the Jorda, Schularick, and Taylor Macrohistory database (2016) shows that US house prices have appreciated significantly in real terms in recent decades. Adjusted for inflation, US house prices are about twice as high than they were in the 1970s. While part of this can be attributed to increases in the size and the quality of dwellings, house prices have appreciated even while holding those two attributes constant. Moreover, the increase in real house prices is not just an American phenomenon (Knoll et al., 2017). Across most advanced economies, inflation-adjusted house prices have appreciated significantly since the 1980s (see figure 3 in the appendix). Part of the phenomenon can be attributed to lower global real interest rates, which would put upward pressure on the fundamental value of financial assets, including dwellings, since all future cash flows are now discounted with a lower rate of interest. At the same time, we have observed in recent years an increase in agglomeration economies. As the major metropolitan areas in the US and many other advanced economies produce an increasing share of national output, it is especially in these areas where house prices have appreciated the most as higher demand has been facing more or less inelastic supply, at least in the short to medium run. There is a lot of evidence that higher house prices also translate into higher rents. Furthermore, as house prices appreciate, this will also put upward pressure on imputed rents of owner-occupied hosuing units. It is especially important to emphasize the importance of lower real interest rates here, since they affect imputed rents in two ways. First, they positively affect the fundamental value of house prices. Second, the decline in real interest rates on the macroeconomic level has been associated with a similar decline of interest rates for mortgages. Figure 4 in the appendix displays the effective nominal interest rate for all mortgages in the US since the late 1970s, which has declined from more than 10% to about 4% as of 2016. While part of the decline is due to the Fisher effect, i.e. a lower rate of inflation translates one to one to a decline in the nominal rate of interest in the long-run, interest rates have been on a secular downward trend even with inflation staying constant because global forces have put downward pressure on real interest rates internationally (Summers, 2015). Associated with the decline in interest rates, there has been a decline in total mortgage payments as a share of GDP, decreasing from about 4% in the early 2000s to just a little more than 2% as of today.

8. The adjusted wage share series for the US

Finally, we also compute economy-wide taxes on production less subsidies as a share of total GDP. Given that these taxes are occurred during the production process, it is not entirely clear whether it is capital or labor, which pays for them. Consequently, we follow Bridgman (2018) and net them out when computing the adjusted wage share. Note that these taxes do not include corporate or personal income taxes, which are both included in measured labor and capital income (Bridgman, 2018).

The most important graph of this paper is thus figure 5, which displays the adjusted wage share net of depreciation, imputed rents, and taxes on production less subsidies. The graph reveals a striking implication: While there are certainly some minor fluctuations that have occurred throughout the business cycle, one cannot detect in any meaningful way a secular downward trend in our adjusted net wage share series in the case of the US. Since a lot of previous research that has discussed the long-run secular decline in the wage share has relied on the gross figure, they have seem to have misidentified the source of the secular downward trend that has occurred in recent decades. Our adjusted series shows that it is entirely due to the two factorless income streams mentioned above, depreciation and imputed rents, as well as netting out taxes on production less subsidies, which have remained fairly stable in recent years (see figure 4 in the appendix). While the "net" or adjusted wage share thus calculated is still some 2 percentage points below its peak in 2008, the current weakness seems to be mostly a result of the business cycle and the very weak economy in the aftermath of the financial crisis. The previous ups and downs seem to be mostly a result of business cycle fluctuations, with the wage share usually moving in a procyclical manner in many advanced economies due to the stickiness of wages (Schneider, 2011).

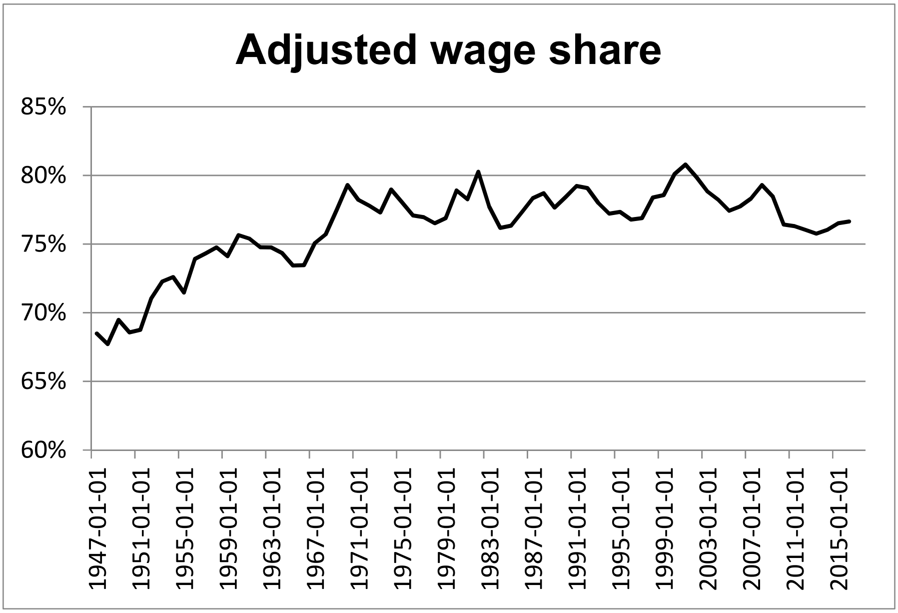

Figure 5
Wage share adjusted for depreciation, imputed rents, and production taxes less subsidies. Source: FRED

Table 1: Annual financials for Mc Donald's Corporation: Fiscal year is January-December. All values USD millions. Source: McDonald's Corporation, Financial statement

	2013	2014	2015	2016	2017
Sales/Revenue	28.11B	27.44B	25.41B	24.62B	22.82B
Cost of Goods Sold (COGS) incl. D&A	17.2B	16.99B	15.62B	14.42B	12.2B
COGS excluding D&A	15.62B	15.34B	14.07B	12.9B	10.84B
Depreciation & Amortization Expense	1.59B	1.64B	1.56B	1.52B	1.36B
Depreciation	1.5B	1.54B	1.44B	1.39B	1.23B
Amortization of Intangibles	86.3M	105.2M	117.7M	125.8M	135.9M
Gross Income	10.9B	10.46B	9.79B	10.2B	10.62B

9. McDonald's Corporation as a case study

Table 1 above displays the annual financials for the McDonald's corporation for the last few years. The company is an interesting case study because it shows how the aforementioned changes to the tax code concerning depreciation of fixed assets can have a significant effect on a corporations' cash flow and earnings. According to its own CEO, McDonald's is not really in the business of selling burgers anymore, at least not exclusively. In fact, it is actually rather a real estate company that just happens to lease out its properties to Burger businesses (the franchise model). Some 85% of its more than 36.000 stores worldwide are actually leased out and a significant portion of its revenue and profit margin is a direct result of this franchising business. According to a report by Wall Street Survivor, the company actually keeps more than 80% of its revenue generated by franchises. McDonald's Corporation can therefore be characterized as a real estate company with some 30 billion USD in real estate assets. Depreciation expensens amount to about 1.4 billion dollars annually in recent years, all of which can be offset against the company's taxable income and therefore directly increases McDonald's annual cash flow (Peterson, 2014).

Similarly, many corporations, both in the US but also in Europe and other high-income countries, have become more adept at exploiting loopholes in the national tax code. One very popular trick that international companies engage in is, for example, to shift intangible assets around the world to low-tax havens in order to maximize their profits and minimize their taxable income. New research has estimated that the annual loss in annual taxes for advanced economies easily amounts to some 40 billion dollars annually or more, given that some 600 billion dollars of profits are shifted to a few tax havens (Alstadsæter et al., 2018).

Table 2:
Change in gross vs. change in net labor share (in percentage points) from 1978 to 2010

Country	Change in gross capital share	Change in net capital share
Australia	4.38	5.77
Austria	7.25	4.42
Belgium	0.89	-2.70
Canada	0.30	-1.72
Denmark	2.73	-0.14
Finland	7.61	7.96
France	1.09	-0.23
Germany	9.04	9.82
Ireland	12.85	11.41
Japan	1.46	-1.51
Netherlands	5.81	4.06
New Zealand	0.90	1.11
Norway	12.70	13.60
Sweden	-0.07	-2.11
United Kingdom	-0.13	1.49
United States	4.67	4.69
Average	4.47	3.5
Correlation	0.95	

Source: Bengtsson and Waldenström (2015) capital share database

10. International evidence

We also have a lot of international data pointing towards the fact that depreciation rates are rising across countries. While some papers find that gross labor shares and net labor shares are, in general, moving in the same direction, there is some conflicting evidence. We use data from the Bengtsson-Waldenström capital share database who have calculated gross capital shares as well as net capital shares for a panel of advanced economies for the last century. Bengtsson and Waldenström (2015) measure the gross capital share as the sum of all interest rate payments, profits, dividends, and realized capital gains divided by gross national income. The data also makes an adjustment for self-employment if possible, i.e. when data availability on a per country basis allows for such a correction[4]. The database also includes the net capital share, which is defined as net capital income over net GDP. This alternative series has the advantage of being adjusted for depreciation. Table 2 above displays the change in the gross capital share vs. the change in the

[4] Historical figures for self-employment are not always available and possibly quite inaccurate.

net labor share for 16 economies from 1987 to 2010. While the two move generally together, there are some notable exceptions. More specifically, Belgium, Canada, Denmark, France, and Japan have experienced an increase in the gross capital share while simultaneously experiencing a decline in the net capital share of GDP over the time period in question. For Sweden, the gross share has stayed basically constant while the net capital share has declined by more than two percentage points. All of this implies that for the aforementioned countries, the depreciation share has risen at the expense of gross factor incomes.

Figure 5 below displays average the gross capital share and the average net capital share for a sample of 17 advanced economies for a time speriod going back to the late 19th century. One can observe the U-shaped pattern for the capital share over the course of the last 150 years, assuming high values both at the beginning as well as at the end of the 20th century. Data from Piketty (2014) and Bengtsson and Waldenström (2018) confirms that it was rather the postwar period when the labor share was extremely high, which was the aberration from the norm. The two World Wars and the Great Depression led to an enormous destruction of capital worlwide and took many advanced economies a couple of decades to recover (Piketty, 2014). While the figure confirms that both the gross and the net capital share tend to move in the same direction, one can see that the average net capital share has not increased by as much as the gross measure, thus confirming that rising depreciation has played a substantial role in suppressing the gross wage share across advanced economies in recent decades. Figure 6 below displays the average economy-wide depreciation share of GDP for 12 advanced economies in the sample. The depreciation share of GDP has increased by about 3 percentage points, on average, from about 12% in the postwar period to about 15% as of today. The US is thus by far not an outlier. While for some economies this is also the natural consequence of capital deepening, i.e. an increase in the capital to GDP ratio, for the US and arguably for many other advanced economies it is mostly the result of compositional changes as we employ more capital that is not as durable as it used to be, mostly ICT technologies. We have also calculated the implied depreciation share across a larger sample of OECD countries by comparing gross national income and net national income from 1970 onwards. Figure 5 in the appendix shows how the depreciation share across OECD economies has increased from about 14 to 18% of GDP over the time period under consideration. Finally, data from Alstadsæter et al. (2018) shows that a significant part of the corporate

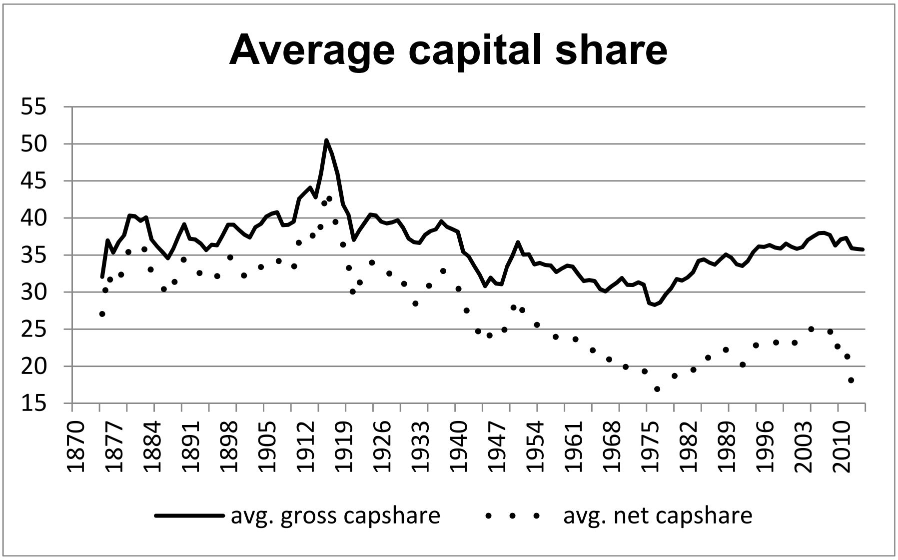

Figure 5:
Average gross and net capital share across advanced economies since the late 19th century. Source: Bengtsson and Waldenström (2015) capital share database

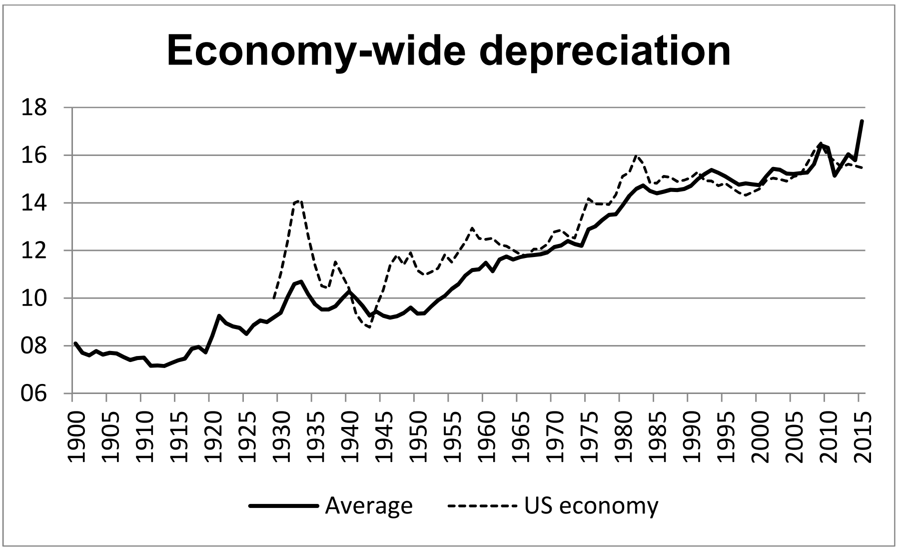

Figure 6:
Economy-wide depreciation share of GDP across advanced economies since 1900. Source: Bengtsson and Waldenström (2015) capital share database

depreciation expenses occur in low-tax havens like Ireland, for example. International corporations increasingly shift their corporate profit as well as intangible assets across borders to minimize their taxable profits, thus also explaining why the depreciation share of corporate gross income is higher in these low-tax jurisdiction compared to that of other high-income regions (see table 6 in the appendix).

12. International evidence on imputed rents

Figure 6 in the appendix displays long-run data for international house prices across advanced economies from the late 19th century to today. One can see that the explosion of inflation-adjusted house prices is a rather novel phenomenon that seems to have started in the late 1970s (Knoll et al., 2017), which corresponds to the end of the Bretton Woods system of fixed exchange rates and the gradual liberalization of international capital flows. Increasing financialization across OECD countries has led to rising indebtedness, especially when it comes to private sector mortgages (Turner, 2017). More recently, mortgage to GDP ratios in certain countries have approached some 100% of GDP, not only in the Anglo-Saxon economies, but even in the social-democratic Scandinavian economies (Jorda et al., 2016a). This spectacular increase in global house prices also had the obcious side effect of leading to a higher imputed rent share in the national accounts. Obviously, some countries are more affected than others, given that home ownership varies widely across OECD economies. Komolafa (2018) calculates the ratio of imputed rents as a share of total rent payments for all EU countries for the year 2016. Her study shows that it ranges from a low of less than 60% in the "renter nation" Germany to more than 70% in Southern Europe, and even exceeding some 90% in some Eastern European economies where home ownership is much more common. While for many countries data on imputed rents has not been collected for a very long time, we have some tentative evidence that these imputations have also been increasing for advanced economies other than the US. In the case of the UK, for example, the imputed rent share increased within just 10 years from a little more than 8% of GDP in 1997 to almost 10% in 2013 (see table 7 in the appendix). Furthermore, many other European economies seem to have experienced a similar trend as rising house prices on the national level push up the imputed rent share. However, one must proceed with caution when comparing imputed rents across countries. As outline above, there are several distinct methodologies that one can use to estimate these imputations. Given that not all countries adhere to the same standards and rules, there might be serious limitations in comparability when using international data (Juntto and Reijo, 2010).

13. Conclusion

There has been a lot of discussion in recent years about the fact that the aggregate labor share of GDP has fallen over the last few decades. While this is certainly true for the gross labor share, net labor shares in some advanced economies have not always moved in the same direction, thus suggesting that part of the explanation is simply an increasing share of capital depreciation. While it is true that the gross labor share for the private sector in the US has declined even further, the picture seems to be more nuanced once we disaggregate the data by sector. For the US economy, we have found that deprecation has increased from less than 5% to more than 10% as a share of gross value added for private industries since the postwar period. Moreover, a sectoral decomposition shows that depreciation rates have mostly increased in the sectors that have also experienced a decline in the within labor share of gross value added.

Furthermore, data from the BEA shows that a significant share of the rise in capital consumption allowance cannot be attributed to a capital deepening effect. The net stock of total private fixed assets, both at historic cost as well as at current cost, has stayed relatively constant in recent decades. This suggests that there are compositional changes at work. We have found that it is especially Intellectual Property Products that account for an increasing fraction of the net stock of private fixed assets, rising from less than 4% of GDP to more than 14% of GDP since Wor;d War II. The increasing importance of intangible assets in today's economy, such as patents and brand names, therefore also has global macroeconomic implications. For the US economy, we have found a significant increase in the economy-wide depreciation share, which is mostly the result of intangible assets.

A second item that has increased markedly in recent years as a share of GDP is related to housing services. Imputed rents are calculated as the net output of owner-occupied housing services. While the housing stock has increased roughly in line with population growth, housing prices have been rising significantly in recent decades, even after adjusting for inflation. Simultaneously, there has been a marked decline in real interest rates over the last couple of decades, not only in the US, but also across most advanced economies (Summers, 2015). This puts downward pressure on aggregate mortgage payments, which are deducted as a cost from homeowners' derived housing output. The general rise in house prices combined with the decline in mortgage payments has generated an increase in the imputed rent share of GDP from about 6% to 8% of GDP over the last four decades.

At least for the US, we can assert that it is those two items alone, the general increase in depreciation combined with the rise of imputed rents, that can account for the largest fraction of the decline in the aggegrate gross labor share, thus putting some doubt on many of the alternative theories that have been put forward more recently. Given that those two items do not represent an income stream to any factor of production but are mere imputations in the GDP calculations, it might make sense to net them out entirely when calculating aggegrate factor shares. We have seen above that the rising share of depreciation is not only a US specific trend, but a phenomenon that can be observed across most advanced economies. While it is certainly an extremely important macroeconomic trends, it also seems to be a somewhat neglected topic on the macroeconomic research agenda.

The increasing importance of these imputations in national GDP figures also raises a few conceptual questions concerning the accuracy of our GDP calculations. First, there might be measurement errors involved, given that both depreciation and imputed rents do not capture any actual income streams, but have to be estimated instead. Second, if national economies have to use an increasing share of GDP simply to replace obsolete capital structures, then real growth rates might actually be somewhat lower than previously thought.

Finally, the rise of imputed rents seems to be an important factor across other advanced economies as well, given that they have seen similar or sometimes even more pronounced house price appreciations compared to the US in recent decades. It is still an open to debate and an avenue for future research to what extent these imputations, rising depreciation rates and higher imputed rents as a share of GDP, can explain the declining gross labor share of income across other advanced economies.

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Appendix A:

This appendix contains additional tables and figures that were not put in the main body of the paper.

Table 1:
Labor share per sector

	Labor share					Change in labor share		
	1947	**1970**	**1986**	**1987**	**2016**	**1947-1970**	**1970-1986**	**1987-2016**
GDP								
Private industries	53.2	59.4	57.6	56	53.7	6.2	-1.8	-2.3
Agriculture, forestry, fishing, and hunting	51.7	55.1	53.2	52.4	49.8	3.4	-1.9	-2.6
Mining	15.6	21.1	25.5	20.1	30.5	5.5	4.4	10.4
Utilities	44.7	35.5	34.1	40.4	29.1	-9.3	-1.3	-11.3
Construction	41.7	32.7	29.2	24.6	27.9	-9.0	-3.4	3.3
Manufacturing	68.1	73.1	71.4	63.7	46.4	5.0	-1.7	-17.3
Wholesale trade	53.0	53.4	55.9	54.1	46.5	0.3	2.5	-7.6
Retail trade	51.0	59.8	59.4	60.5	53.8	8.8	-0.3	-6.7
Transportation and warehousing	70.6	69.7	65.0	68.8	59.2	-0.9	-4.7	-9.6
Information	59.8	45.6	40.7	39.9	36.3	-14.2	-4.8	-3.6
Finance, insurance, real estate, rental, and leasing	19.0	21.1	23.8	23	22.5	2.1	2.7	-0.5
Professional and business services	59.3	63.9	64.4	66.1	73.5	4.7	0.5	7.4
Educational services, health care, and social assistance	48.1	66.8	80.3	79.7	85	18.8	13.5	5.3
Arts, entertainment, recreation, accommodation, and food services	51.7	57.7	58.6	61.4	61.9	6.0	0.9	0.5
Other services, except government	75.9	68.9	61.5	60.9	70.9	-7.0	-7.5	10
Government	64.4	83.5	84.8	77.7	79.6	19.1	1.3	1.9
Unweighted average	51.7	54.2	54.1	53.1	51.7	2.5	-0.1	-1.4

Table 2:
Output share per sector

	Output share					Change in output share		
	1947	**1970**	**1986**	**1987**	**2016**	**1947-1970**	**1970-1986**	**1987-2016**
Private industries	83.2	85.7	85.7	87.1	-3.3	2.5	1.4	-2.3
Agriculture, forestry, fishing, and hunting	2.5	1.6	1.6	1.0	-5.5	-0.9	-0.6	-2.6
Mining	1.4	1.5	1.5	1.4	-0.9	0.1	-0.1	10.4
Utilities	2.0	2.6	2.6	1.5	0.6	0.6	-1.1	-11.3
Construction	4.6	4.3	4.3	4.3	1.0	-0.3	0.0	3.3
Manufacturing	22.9	18.1	18.1	11.7	-2.5	-4.8	-6.4	-17.3
Wholesale trade	6.3	6.1	5.9	5.9	0.1	-0.2	0.0	-7.6
Retail trade	7.7	7.2	7.1	5.9	-1.6	-0.5	-1.2	-6.7
Transportation and warehousing	3.7	3.2	3.1	3.0	-2.0	-0.5	-0.1	-9.6
Information	3.8	4.6	4.6	4.9	0.7	0.8	0.3	-3.6
Finance, insurance, real estate, rental, and leasing	14.2	17.6	17.5	20.9	3.9	3.4	3.4	-0.5
Professional and business services	4.9	7.8	8.0	12.1	1.6	2.9	4.1	7.4
Educational services, health care, and social assistance	3.8	5.4	5.7	8.4	2.0	1.6	2.7	5.3
Arts, entertainment, recreation, accommodation, and food services	2.8	3.2	3.2	4.0	-0.4	0.4	0.8	0.5
Other services, except government	2.6	2.5	2.5	2.2	-0.4	-0.1	-0.3	10
Government	16.8	14.3	14.3	12.9	3.3	-2.5	-1.4	1.9
Unweighted average	51.7	54.2	54.1	53.1	51.7	2.5	-0.1	-1.4

Table 3.1:
Changes in the weighted labor share and decomposition. 1947 - 1970

	Weighted labor share	Within effect	Structural effect	Product
Private industries	0.0339	0.0535	-0.0176	-0.0020
Agriculture, forestry, fishing, and hunting	-0.0276	0.0028	-0.0284	-0.0019
Mining	-0.0006	0.0013	-0.0014	-0.0005
Utilities	0.0008	-0.0013	0.0027	-0.0006
Construction	0.0000	-0.0032	0.0042	-0.0009
Manufacturing	-0.0056	0.0127	-0.0170	-0.0012
Wholesale trade	0.0007	0.0002	0.0005	0.0000
Retail trade	-0.0014	0.0082	-0.0082	-0.0014
Transportation and warehousing	-0.0144	-0.0005	-0.0141	0.0002
Information	-0.0012	-0.0044	0.0042	-0.0010
Finance, insurance, real estate, rental, and leasing	0.0104	0.0022	0.0074	0.0008
Professional and business services	0.0118	0.0015	0.0095	0.0007
Educational services, health care, and social assistance	0.0167	0.0034	0.0096	0.0038
Arts, entertainment, recreation, accommodation, and food services	-0.0004	0.0019	-0.0021	-0.0002
Other services, except government	-0.0048	-0.0021	-0.0030	0.0003
Government	0.0533	0.0258	0.0213	0.0063
Sum	0.0377	0.0483	-0.0149	0.0043

Table 3.2:
Changes in the weighted labor share and decomposition. 1970 - 1986

	Weighted labor share	Within effect	Structural effect	Product
Private industries	-0.0006	-0.0150	0.0149	-0.0004
Agriculture, forestry, fishing, and hunting	-0.0053	-0.0005	-0.0050	0.0002
Mining	0.0009	0.0006	0.0002	0.0000
Utilities	0.0018	-0.0003	0.0021	-0.0001
Construction	-0.0025	-0.0016	-0.0010	0.0001
Manufacturing	-0.0382	-0.0040	-0.0351	0.0008
Wholesale trade	0.0005	0.0016	-0.0011	-0.0001
Retail trade	-0.0032	-0.0002	-0.0030	0.0000
Transportation and warehousing	-0.0050	-0.0018	-0.0035	0.0002
Information	0.0014	-0.0018	0.0036	-0.0004
Finance, insurance, real estate, rental, and leasing	0.0120	0.0039	0.0072	0.0009
Professional and business services	0.0189	0.0002	0.0185	0.0001
Educational services, health care, and social assistance	0.0180	0.0051	0.0107	0.0022
Arts, entertainment, recreation, accommodation, and food services	0.0026	0.0003	0.0023	0.0000
Other services, except government	-0.0026	-0.0019	-0.0007	0.0001
Government	-0.0190	0.0023	-0.0209	-0.0003
Sum	-0.0197	0.0019	-0.0255	0.0039

Table 3.3:
Changes in the weighted labor share and decomposition. 1987 - 2016

	Weighted labor share	Within effect	Structural effect	Product
Private industries	-0.0122	-0.0197	0.0078	-0.0003
Agriculture, forestry, fishing, and hunting	-0.0034	-0.0004	-0.0031	0.0002
Mining	0.0013	0.0016	-0.0002	-0.0001
Utilities	-0.0061	-0.0029	-0.0044	0.0012
Construction	0.0014	0.0014	0.0000	0.0000
Manufacturing	-0.0610	-0.0313	-0.0408	0.0111
Wholesale trade	-0.0045	-0.0045	0.0000	0.0000
Retail trade	-0.0112	-0.0048	-0.0073	0.0008
Transportation and warehousing	-0.0036	-0.0030	-0.0007	0.0001
Information	-0.0006	-0.0017	0.0012	-0.0001
Finance, insurance, real estate, rental, and leasing	0.0068	-0.0009	0.0078	-0.0002
Professional and business services	0.0361	0.0059	0.0271	0.0030
Educational services, health care, and social assistance	0.0260	0.0030	0.0215	0.0014
Arts, entertainment, recreation, accommodation, and food services	0.0051	0.0002	0.0049	0.0000
Other services, except government	0.0004	0.0025	-0.0018	-0.0003
Government	-0.0084	0.0027	-0.0109	-0.0003
Sum	-0.0219	-0.0321	-0.0067	0.0169

Table 4.1:
Current cost depreciation as a share of gross value added

Total depreciation	**Depreciation as a share of gross value added**					**Change in depreciation share**		
	1947	**1970**	**1986**	**1987**	**2016**	**1947-1970**	**1970-1986**	**1987-2016**
Private industries	0.082	0.110	0.135	0.136	0.147	0.028	0.025	0.012
Agriculture, forestry, fishing, and hunting	0.060	0.194	0.267	0.244	0.321	0.134	0.073	0.077
Mining	0.173	0.312	0.488	0.424	0.551	0.139	0.177	0.127
Utilities	0.202	0.212	0.239	0.236	0.300	0.010	0.027	0.064
Construction	0.045	0.053	0.041	0.039	0.050	0.008	-0.012	0.011
Manufacturing	0.057	0.100	0.145	0.146	0.195	0.043	0.045	0.049
Wholesale trade	0.026	0.040	0.077	0.080	0.068	0.014	0.037	-0.011
Retail trade	0.026	0.031	0.047	0.049	0.076	0.005	0.015	0.028
Transportation and warehousing	0.162	0.174	0.190	0.188	0.161	0.012	0.017	-0.026
Information	0.142	0.216	0.206	0.212	0.251	0.073	-0.010	0.039
Finance, insurance, real estate, rental, and leasing	0.179	0.157	0.180	0.188	0.192	-0.023	0.023	0.003
Professional and business services	0.012	0.027	0.031	0.033	0.047	0.014	0.005	0.014
Educational services, health care, and social assistance	0.065	0.072	0.081	0.079	0.084	0.006	0.010	0.006
Arts, entertainment, recreation, accommodation, and food services	0.099	0.120	0.103	0.103	0.078	0.020	-0.017	-0.025
Other services. except government	0.027	0.068	0.066	0.067	0.080	0.041	-0.002	0.014
Government								
Unweighted average	0.091	0.126	0.153	0.148	0.174	0.035	0.028	0.025

Table 4.2:
Current cost depreciation of equipment as a share of gross value added

Equipment	Depreciation as a share of gross value added					Change in depreciation share		
	1947	**1970**	**1986**	**1987**	**2016**	**1947-1970**	**1970-1986**	**1987-2016**
Private industries	0.037	0.054	0.065	0.065	0.054	0.017	0.011	-0.012
Agriculture, forestry, fishing, and hunting	0.045	0.161	0.221	0.202	0.275	0.116	0.060	0.074
Mining	0.052	0.119	0.183	0.170	0.103	0.068	0.063	-0.067
Utilities	0.087	0.106	0.148	0.148	0.150	0.019	0.042	0.002
Construction	0.045	0.051	0.037	0.036	0.045	0.006	-0.013	0.009
Manufacturing	0.036	0.052	0.074	0.074	0.069	0.016	0.021	-0.004
Wholesale trade	0.026	0.037	0.068	0.070	0.036	0.011	0.031	-0.034
Retail trade	0.013	0.019	0.028	0.030	0.040	0.006	0.009	0.010
Transportation and warehousing	0.085	0.124	0.146	0.145	0.119	0.040	0.022	-0.026
Information	0.052	0.104	0.105	0.106	0.065	0.052	0.000	-0.040
Finance, insurance, real estate, rental, and leasing	0.023	0.032	0.041	0.044	0.045	0.009	0.009	0.001
Professional and business services	0.012	0.013	0.012	0.013	0.014	0.001	-0.002	0.001
Educational services, health care, and social assistance	0.022	0.040	0.052	0.051	0.051	0.018	0.013	0.000
Arts, entertainment, recreation, accommodation, and food services	0.050	0.067	0.056	0.055	0.036	0.017	-0.011	-0.019
Other services. except government	0.013	0.039	0.037	0.037	0.034	0.026	-0.002	-0.003
Government								
Unweighted average	0.040	0.068	0.085	0.083	0.076	0.028	0.017	-0.007

Table 4.3:
Current cost depreciation of dependent structures as a share of gross value added

Intellectual Property	Depreciation as a share of gross value added					Change in depreciation share		
	1947	**1970**	**1986**	**1987**	**2016**	**1947-1970**	**1970-1986**	**1987-2016**
Private industries	0.038	0.039	0.048	0.048	0.053	0.001	0.009	0.005
Agriculture, forestry, fishing, and hunting	0.015	0.033	0.046	0.043	0.044	0.018	0.013	0.002
Mining	0.121	0.192	0.302	0.248	0.435	0.071	0.109	0.187
Utilities	0.115	0.106	0.083	0.081	0.135	-0.009	-0.023	0.055
Construction	0.000	0.002	0.003	0.003	0.003	0.002	0.001	0.000
Manufacturing	0.011	0.011	0.015	0.015	0.016	0.000	0.004	0.001
Wholesale trade	0.000	0.001	0.005	0.005	0.007	0.001	0.004	0.002
Retail trade	0.013	0.012	0.016	0.016	0.023	-0.001	0.004	0.006
Transportation and warehousing	0.078	0.050	0.043	0.042	0.034	-0.028	-0.006	-0.008
Information	0.026	0.024	0.023	0.023	0.027	-0.002	-0.002	0.004
Finance, insurance, real estate, rental, and leasing	0.156	0.122	0.132	0.137	0.132	-0.034	0.010	-0.006
Professional and business services	0.000	0.002	0.002	0.002	0.002	0.002	0.000	0.000
Educational services, health care, and social assistance	0.022	0.012	0.010	0.010	0.013	-0.009	-0.002	0.003
Arts, entertainment, recreation, accommodation, and food services	0.037	0.033	0.029	0.029	0.028	-0.004	-0.004	-0.001
Other services. except government	0.013	0.025	0.024	0.025	0.027	0.012	-0.001	0.002
Government								
Unweighted average	0.043	0.044	0.052	0.048	0.065	0.001	0.008	0.017

Table 4.4:
Current cost depreciation of IP as a share of gross value added

Dependent structures	Depreciation as a share of gross value added					Change in depreciation share		
	1947	1970	1986	1987	2016	1947-1970	1970-1986	1987-2016
Private industries	0.016	0.022	0.023	0.023	0.040	0.005	0.001	0.018
Agriculture, forestry, fishing, and hunting	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.002
Mining	0.000	0.006	0.004	0.004	0.013	0.006	-0.002	0.009
Utilities	0.000	0.008	0.008	0.008	0.015	0.008	0.000	0.007
Construction	0.000	0.001	0.000	0.000	0.002	0.001	0.000	0.002
Manufacturing	0.036	0.056	0.057	0.057	0.109	0.020	0.001	0.052
Wholesale trade	0.000	0.004	0.004	0.004	0.025	0.004	0.000	0.021
Retail trade	0.000	0.002	0.003	0.003	0.014	0.002	0.000	0.011
Transportation and warehousing	0.002	0.001	0.001	0.001	0.009	-0.001	0.000	0.007
Information	0.087	0.079	0.083	0.083	0.159	-0.009	0.005	0.076
Finance, insurance, real estate, rental, and leasing	0.003	0.006	0.007	0.007	0.015	0.004	0.001	0.008
Professional and business services	0.011	0.018	0.019	0.019	0.031	0.006	0.001	0.012
Educational services, health care, and social assistance	0.040	0.052	0.051	0.051	0.051	0.013	-0.001	0.000
Arts, entertainment, recreation, accommodation, and food services	0.023	0.019	0.020	0.020	0.014	-0.005	0.001	-0.005
Other services. except government	0.004	0.005	0.006	0.006	0.019	0.002	0.001	0.013
Government								
Unweighted average	0.015	0.019	0.019	0.019	0.035	0.004	0.001	0.016

Table 5:
IRS Asset description and class life

IRS Asset Classes	Asset Description	ADS Class Life	GDS Class Life
00.11	Office furniture, fixtures, and equipment	10	7
00.12	Information systems: computers/peripherals	6	5
00.22	Automobiles, taxis	5	5
00.241	Light general-purpose trucks	4	5
00.25	Railroad cars and locomotives	15	7
00.40	Industrial steam and electric distribution	22	15
01.11	Cotton gin assets	12	7
01.21	Cattle, breeding or dairy	7	5
13.00	Offshore drilling assets	7.5	5
13.30	Petroleum refining assets	16	10
15.00	Construction assets	6	5
20.10	Manufacture of grain and grain mill products	17	10
20.20	Manufacture of yarn, thread, and woven fabric	11	7
24.10	Cutting of timber	6	5
32.20	Manufacture of cement	20	15
20.1	Manufacture of motor vehicles	12	7
48.10	Telephone distribution plant	24	15
48.2	Radio and television broadcasting equipment	6	5
49.12	Electric utility nuclear production plant	20	15
49.13	Electric utility steam production plant	28	20
49.23	Natural gas production plant	14	7
50.00	Municipal waste water treatment plant	24	15
57.0	Distributive trades, and services	9	5
80.00	Theme and amusement park assets	12.5	7

Source: IRS

Table 6:
Corporate depreciation by world region in 2016 (in billions of US dollars)

	Gross corporate output	Corporate depreciation	Corporate depreciation share
United States	9 870	1 551	0.157
European Union	8 227	1 424	0.173
Other OECD countries	7 118	1 396	0.196
Developing countries	13 859	2 165	0.156
Tax havens	1 939	393	0.202
World total	41 012	6 929	0.169

Source: Alstadsæter et al. (2018)

Table 7:
Imputed rent share of GDP for the UK

Year	Imputed rent share of GDP
1997	8.26%
1998	8.24%
1999	8.39%
2000	8.44%
2001	8.51%
2002	8.52%
2003	8.55%
2004	8.60%
2005	8.66%
2006	8.69%
2007	8.75%
2008	9.06%
2009	9.51%
2010	9.47%
2011	9.44%
2012	9.56%
2013	9.67%

Source: ONS

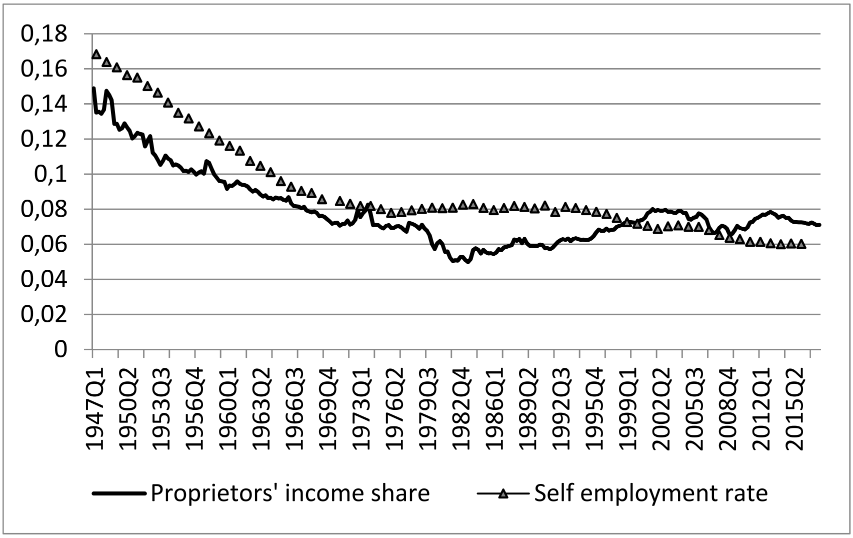

Figure 1:

Proprietors' income as a share of GDP and self-employment ratio. Source: BEA

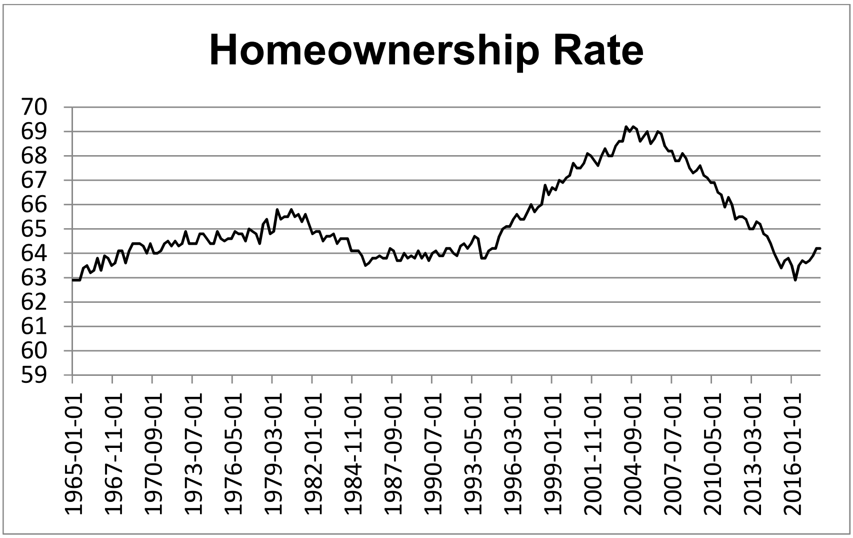

Figure 2:

Homeownership rate in the US. Source: FRED

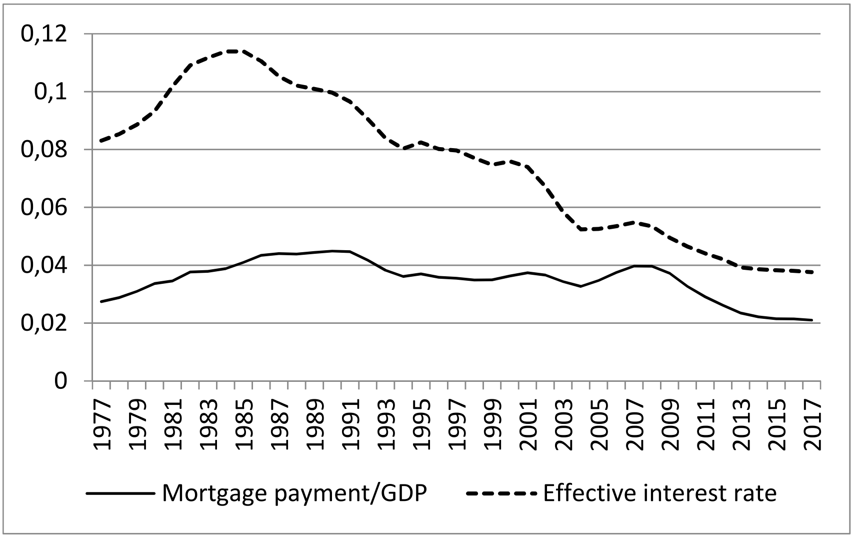

Figure 3:
Mortgage payments as a share of GDP and the effective interest rate. Source: BEA

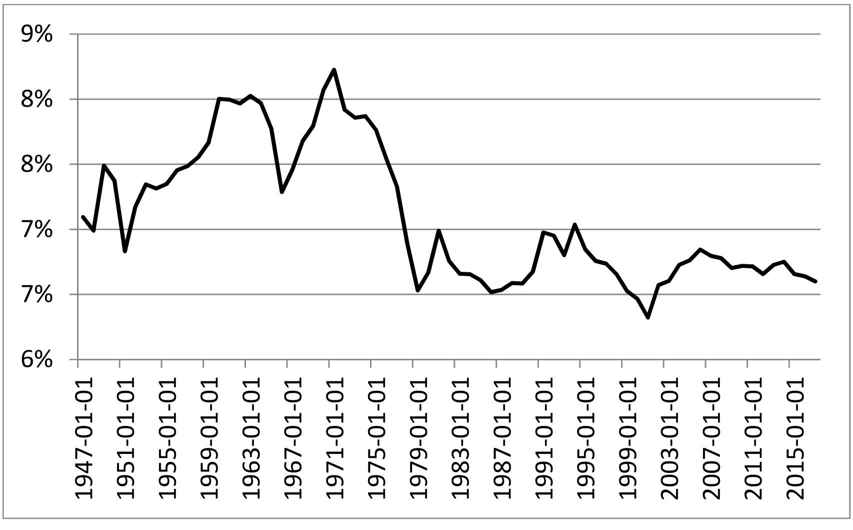

Figure 4:
Taxes on production less subsidies as a share of GDP. Source: FRED

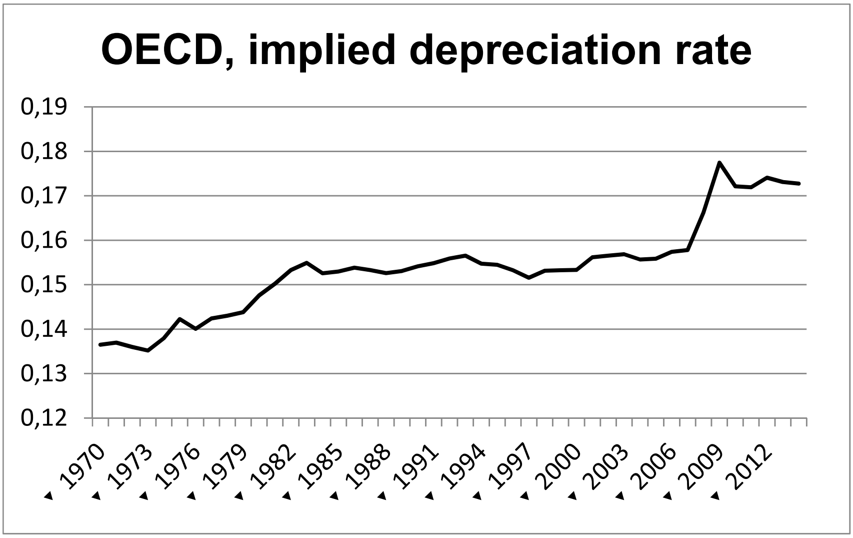

Figure 5:
Average depreciation rate across OECD countries. Source: OECD

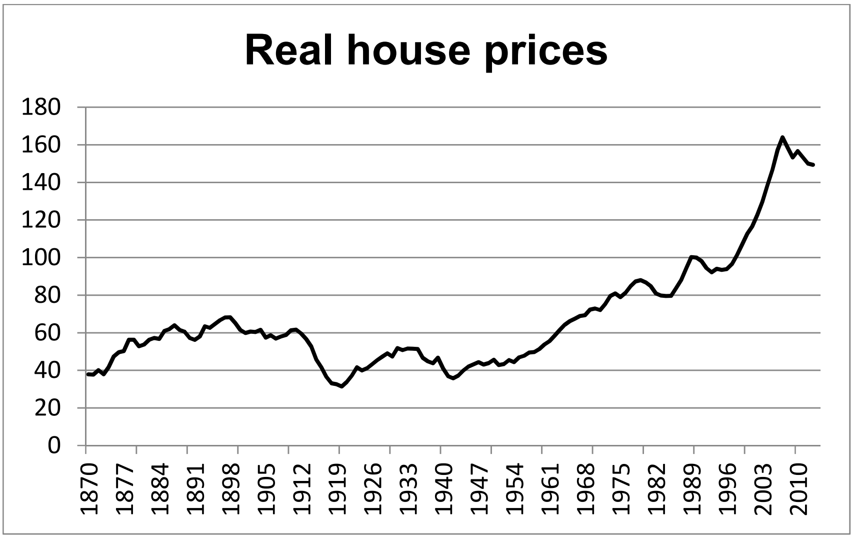

Figure 6:
Average real house prices across a sample of 17 advanced economies. Source: Jorda, Schularick and Taylor (2016a) Macroeconomic history database

Appendix B:

This section briefly outlines the changes to the tax code that were made during the Reagan administration regarding the treatment of property and depreciation rules:

The Accelerated Cost Recovery System (ACRS) was adopted by Congress in in 1981 as part of the Economic Recovery Tax Act as a method of depreciating property for tax purposes. The law allows individuals and businesses to write off capitalized assets in an accelerated manner. The ACRS assigns assets to one of eight recovery classes, which are ranging from 3 to 19 years, depending on the assets' useful lives. These recovery classes are used as the basis for depreciation of the assets in question. The basic idea behind ACRS was to increase the tax deduction for depreciation of property and thus increase the cash flow available to individuals and businesses for investment (Darney et al., 2007).

The law was therefore explicitly put in place during the economic recession of 1980, which was caused by contractionary monetary policy (the so-called Volcker recession was caused by the Fed with a series of interest rate hikes that were supposed to bring down the high inflation rates that the US economy had experienced in the prior decade). The aim of the ACRS was therefore to increase corporate cash flow and thus spur business investment (Darney et al., 2007). In fact, at the time it was enacted, ACRS was expected to add between $50 and $100 billion to the incomes of individuals and businesses over a 10-year period (Kaplan, 1985), corresponding to some two to four percent of annual GDP. According to proponents of the law, the new depreciation method could spur the economic recovery by increasing business investment. However, there was also some concern that the changes in the tax law simply made reported business earnings appear better than they actually were:

"The dangers of treating depreciation as merely an accounting convention, and not a real economic cost that provides for the eventual replacement of plant and equipment. This problem would be exacerbated by ACRS, which allowed companies to take ultra rapid depreciation on capital-intensive assets... By reducing corporate tax bills, ACRS also exaggerated the disparity between cash flow and reported earnings. The cash generated by a company's operations is being hailed as a far more reliable barometer of financial health than the more traditional earnings yardstick, which can be skewed by accounting conventions." (Kaplan, 1985).

Finally, the favorable tax treatment of capitalized assets also had the direct consequence of increasing the number of hostile business takeovers, a potentially harmful trend for the economy: "ACRS inadvertently unleashed a potent weapon for corporate raiders who specialize in leveraging the assets of the target company to finance their attacks." (Kaplan, 1985).

In response to criticism, the U.S. Congress revised the ACRS as part of the 1986 Tax Reform Act. The Modified Accelerated Cost Recovery System (MACRS) reduces the annual depreciation deductions granted for residential and non-residential real estate by using longer recovery periods. There was some worry that the changes would increase consumption at the expense of business investment, thereby leading to an adverse effect on economic growth (Darney et al., 2007).

It should be noted that MACRS actually comprises two different depreciation methods. The first is the so-called General Depreciation System (GDS), which is used for most types of property. The Alternative Depreciation System (ADS), on the other hand, only applies to certain types of property: property that is used for business purposes 50 percent of the time or less, is used predominantly outside the United States, or is used for tax-exempt purposes, for example. However, it can also be used if the taxpayer chooses so (Darney et al., 2007).

In March 2004, temporary and proposed changes to MACRS were published by the IRS. In an article discussing these changes, Lynn Afeman notes: "The temporary regulations, fortunately, provide an election out of these rules. However, some taxpayers may make the election simply to avoid complexity, rather than to gain the most advantageous depreciation regime." (Afeman, 2004).

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Paper II

ABSTRACT

Many countries have seen spectacular increases in asset prices and private sector leverage in recent decades. We examine the interaction between the functional distribution of income and asset prices in 17 advanced economies using long-run macroeconomic data that goes back until the end of the 19th century for some of the countries in our panel. Using a Panel-VAR approach, we estimate the relationship between monetary variables, credit, asset prices, and the functional distribution of income. We find the anticipated positive effect between nominal stock price growth and the capital share, and we can also establish Granger causality between the two variables. Our estimated impulse response functions suggest that an innovation to stock price growth leads to an increase in the capital share of about 0.6 to 1.5 percentage points within the subsequent two to three years. On the other hand, we cannot find a positive effect of house prices on the capital share. We also use a more common Panel-OLS model with country and time fixed effects and country-specific time trends to support our previous results. We validate the positive expected relationship between stock prices and the capital share across various specifications. However, the link between house prices and the capital share is less clear and also not robust. According to our Panel-OLS results, an increase in nominal stock prices of 10% is associated with an increase in the capital share of about 0.1 to 0.2 percentage points in the short-run. The current low-growth and low-interest rate regime, sometimes referred to as "secular stagnation", supports rich asset valuations worldwide and might thus also affect factor shares.

Key words:
Functional distribution of income; financialization; debt; asset price growth; income inequality

Financialization, asset prices, and the functional distribution of income: A long-run cross-country analysis

1. Introduction

One of the stylized facts of neoclassical growth theory is that factor shares are relatively constant in the long-run, with some minor fluctuations that occur throughout the business cylce (Jones, 2002). However, numerous empirical studies have revealed that factor income shares are quite unstable even in the medium run (Blanchard et al., 1997). In recent decades many countries have experienced a significant decline in the labor share of income, an empirical result that seems to hold on a global scale (Stockhammer, 2013; Karabarbounis and Neiman, 2013; Bengtsson and Waldenström, 2015). The most influential study about the topic is probably Piketty's "Capital in the 21st century", which popularized the discussion about the functional distribution of income (Piketty, 2014). His data shows that that the capital share of GDP has exhibited a U-shaped pattern over the course of the 20th century, assmuning high values in the beginning and high values at the end of the century. The main theme of Piketty's book is that we can also expect high values for the capital share going forward, as capital to income ratios have recovered from their depressed values in the middle of the 20th century. Furthermore, Piketty (2014), and more recently Rognlie (2015) as well as La Cava (2016), show that the spectacular increase in real house prices over the last decades has led to a much higher capital to income ratio. This also came hand in hand with a higher capital share of income.

In what follows, we further explore the link between asset prices and the capital share. Combining two novel macroeconomic history datasets, the Macrohistory database by Jorda, Schularick, and Taylor (2016a; 2016b) and the Bengtsson-Waldenström (2015) capital share dabase, gives us a rich set of panel data for 17 advanced economies that goes back until the end of the 19th century for some of the countries in our study. The data set is thus more comprehensive than Piketty's (2014) original analysis, which only covers eight advanced economies. The Bengtsson-Waldenström data displays the familiar U-shaped pattern for the capital share across our panel of 17 countries. This result holds both for the gross as well as the net labor share (factoring out depreciation). As depreciation is not an income to any factor of production, focusing on net shares might be more relevant if one is concerned about distributional issues.

The first part of this paper comprises of a literature review of the most important empirical studies on changes in the functional distribution of income. The second part describes some key long-run macroeconomic trends in the countries under considerations for the time period of our study. The main aim of this paper is to assess the impact of rising asset prices on the capital share of GDP, using more than a century of data. We employ several different statistical techniques to estimate the effect of asset price growth on changes in the functional distribution of income. The main empirical strategy used in this paper is the estimation of a Panel-VAR model for our key variables of interest: GDP, monetary and financial variables, asset prices, and the capital share. All of these variables are treated as being endogenousely determined by and "within" the macroeconomy. We follow closely the approach used by Goodhart and Hofmann (2008) who use a very similar model to study the multidirectional link between house prices and monetary variables. The advantage of the Panel-VAR approach is that we can test for Granger causality between the key variables of interest mentioned above. Moreover, the Panel-VAR model also allows us to estimate a set of impulse response function. Last but not least, we use a Panel-OLS model to examine the main macroeconomic variables that have been driving flucutations in the functional distribution of income. This second approach allows us to introduce additional control variables in our specification.

Many advanced economies have seen a spectacular expansion of private sector credit in recent decades. Large increases in real house prices have coincided with a significant increase in the mortgage to GDP ratio. Our statistical analysis suggests a positive relationship between asset prices and credit with bidirectional Granger causality. Moreover, we can confirm the anticipated positive effect of asset price growth on the capital share. In terms of Granger causality, we find that stock prices Granger cause changes in the capital share of income. Our estimated impulse response functions suggest that an innovation to stock price growth increases the capital share by about 0.6 to 1.5 percentage points within the subsequent two to three years, depending on the time period under consideration. In terms of house prices, on the other hand, we cannot detect the anticipated positive effect between house price appreciation and the capital share of income in our Panel-VAR model.

The results from our Panel-OLS analysis also suggest a very strong positive statistical relationship between stock prices and the capital share of income, with an increase of nominal stock prices by 10% being associated with an increase in the capital share of about 0.1 to 0.3 percentage points in the short-run. While we only find weak evidence for a relationship between house prices and the capital share, the result seems to be stronger when we use OECD data for the capital share for the time period after 1970 instead. In terms of our control variables, we find similar results to previous findings in the literature. Most notably, GDP growth and trade openness are positively correlated with the capital share. The output gap, the unionization rate, and the unemployment rate are negatively correlated with the capital share.

2. Literature review

While standard neoclassical growth models usually assume that the labor share is roughly two thirds of output while the remaining one third is capital income (Jones, 2002), economists have known for a long time that factor shares can exhibit marked fluctuations in the medium to long-run (Atkinson, 2009). Piketty's (2014) contribution was to show that the capital to income ratio has exhibited a U-shaped pattern for all major economies with high values in the beginning as well as at the end of the 20th century. The working hypothesis is that the three major global shocks, the two World Wars and the Great Depression, have led to an enourmous destruction of wealth in many advanced economies from which it took several decades to recover. Similarly, the capital share has followed the same U-shaped relationship over the course of the 20th century. While Piketty's (2014) analysis has focused on a time span that covers more than two centuries of data for eight advanced countries, most empirical studies have focused on more recent data. Karabarbounis and Neiman (2013), for example, find a statistically significant decline in the labor share in 37 out of a sample of 59 countries during the period from 1975 to 2012. Furthermore, the same authors show that in a cross-country analysis that 22 out of the 24 countries that experienced a decline in gross labor shares also experienced a decline in net labor shares at the same time. The correlation between the two differet measures is thus extremely high (Karabarbounis and Neiman, 2014).

There are a number of potential economic explanations, which have been offered to explain the phenomenon of the falling labor share of income. Many explanations tend to focus in one way or the other on the bargaining power of labor and monopoly power. Fichtenbaum (2011), for example, suggests that the decline of labor unions is to blame, as it weakens the bargaining power of workers. Indeed, a number of studies have suggested a relationship between the erosion of union power and the declining labor share (Kristal, 2010). Stockhammer (2013), on the other hand, suggests that increasing financialization is to blame. According to his study, global deregulation and liberalization of financial markets have led to a decline in the bargaining power of labor as firms now face a larger number of investment opportunities, both domestic and abroad. This increased flexibility would weaken the relative strength of workers and increase markups. Grenestam and Probst (2014) have estimated markups for different US industries and have confirmed an increase over the last decades, which could explain a significant part of the fall in the labor share. This result was more recently corroborated by Barkai (2016) who also finds an increase in markups and financial profits for the private sector in the US. Autor et al. (2017) suggest that a lot of industries are increasingly dominated by so-called superstar firms, which tend to be highly profitable and low labor share companies. Accordingly, it is the rise in industry concentration that has led to the increase in capital income and monopoly rents. Koh et al. (2014) emphasize that these monopoly rents are largely stemming from IPP (intellectual property rights). The decline in the labor share can thus largely be explained by the rise of IPP, such as patents, and the associated monopoly power that stems from it.

Alternatively, non-neutral technological change can also account for a change in the factor shares. The result, however, is relatively specific to the underlying production function, as emphasized by Hicks (1932). As capital-biased technological change reduces the cost of one unit of effective capital relative to one unit of effective labor, firms face an increased incentive to switch to a more capital-intensive method of production. Whether the capital share will rise as a result, however, is dependent on the elasticity of substitution, i.e. to what degree labor can be substituted for capital and vice-versa. Only if the elasticity is larger than one, that is when capital and labor are highly substitutable, will the capital share actually increase. In the Cobb-Douglas case where the elasticity is equal to unity, non-neutral technological change does not alter the factor shares of income in the long-run. Determining the elasticity of substitution is thus ultimately a matter of empirics. Furthermore, to what extent capital and labor are substitutable surely depends on the time horizon under consideration, that is, the short-run elasticity will be lower than the long-run elasticity. There is also some conflicting evidence on the micro and macro level (Acemoglu and Robinson, 2015). Jones (2003) argues that the long-run production function is likely to be Cobb-Douglas. Karabarbournis and Neiman (2013), on the other hand, estimate that the elasticity of substitution between capital and labor is likely to be about 1.25. Given this parameter value, they find that a large decline in the labor share can be accounted for by the relative decrease in the price of investment (capital goods) in recent decades. This would be in line with Piketty's (2014) estimate that, in general, capital accumulation does not produce a sufficient decline in interest rates to keep the capital share constant. More recently, Grossman et al. (2017) have disputed the assumption that the elasticity of substitution is larger than one. They construct a neoclassical growth model with endogenous human capital accumulation and capital-skill complementary. The authors emphasize that the global productivity slowdown can explain a substantial fraction of the decline in the labor share worldwide. That is because the low-growth and low real interest rate regime ("secular stagnation") raises the returns to high skilled labor and thus leads to an increase in the human capital stock. This, in turn, increases the capital share as high-skilled labor and capital are assumed to be complementary in the model. Tridico and Pariboni (2017), on the other hand, show within a postkeynesian framework that the decline in productivity might be a consequence of the falling wage share instead of being the cause thereof.

3. Asset prices and the functional distribution of income

There are, to the best of our knowledge, very few existing studies that have touched upon the question whether asset price growth might exert downward pressure on the labor share of GDP. According to economic theory, the relationship between asset prices and the functional distribution of income is ambiguous, as the effect depends on the elasticity of substitution between capital and labor (Piketty, 2014). Higher asset prices can theoretically depress interest rates by a sufficient amount so that the capital share actually falls. It is thus ultimately a matter of empirics to determine during which time periods an increase in the capital to income ratio led to a rise in the capital share.

Rognlie (2015) emphasizes that the rise in the capital share can to a large extent be explained by trends in the housing market. Real house prices have appreciated considerably in all advanced economies since the 1970s. This effect has been particularly strong in large metropolitan areas as a result of increasing agglomeration effects while misguided housing policies kept supply artificially low. As a consequence, house owners are able to extract extremely high rents from their underlying assets. This theory is also backed up by La Cava (2016) who finds that housing is the most important driver of the capital share in the US in recent decades. The share of total income flowing to housing services increased from about 3% in the 1950s to 7% nowadays. Interestingly, most of the change is the result of imputed rents, which begs the question whether the rising capital share might simply be a statistical illusion resulting from the methodology of computing imputed rents. The first-round effect of an increase in asset prices is simply an associated increase in capital gains. This would only affect the functional distribution of income if some of these gains are eventually realized. Roine and Waldenström (2012) show that in the case of Sweden realized capital gains have indeed played an important contribution in the role of rising inequality over the last few decades. According to their estimates, realized capital gains have increased from about 1% of total national income in the 1980s to more than 4% in the late 2000s. Moreover, the distributional impact of capital gains appears to be a phenomenon that is more or less exclusively affecting incomes at the very top of the distribution. While Roine and Waldenström (2012) rule out real estate as a transmission mechanism, they point towards the Swedish stock market, which experienced a booming period with annual real gains of 13% and 16% in the 1980s and 1990s, respectively (compare that to more modest growth rates of 3% and 6%, respectively, for the New York stock exchange). There is also a secondary effect, which is that higher asset price valuations ultimately support higher income streams down the line. One might expect this effect to kick in with a time lag of up to several quarters or even years. In the case of stocks, higher valuations might increase dividend payouts. In the case of real estate, higher prices ultimately support higher rents, or higher imputed rents in the case of owner-occupied housing, as suggested by La Cava (2016). High stock prices also affect investment and consumption decisions. According to Tobin (1976), high stock market valuations provide firms an incentive to invest, a theory also known as "Tobin's Q" (the ratio between a physical asset's market value and its replacement cost). A high marginal q implies that investment activities are very attractive, i.e. have a high return. Finally, high asset prices, both stocks as well as real estate, also affect the savings and consumption decisions by households, the so-called wealth effect (Mishkin, 2007a). As rising asset prices affect the investment decisions of firms and the consumption pattern of households, this might also alter the balance between capital income and labor income in the economy. Greenwald et al. (2014), on the other hand, have estimated that a factor shift shock from labor income to capital income can explain a substantial fraction of the increase in the U.S. stock market in recent decades. Their model is based on the assumption of heterogeneous agents. As capitalists own the stock market, a shift from labor to capital income also supports richer equity valuations. We thus also need to address in this paper the issue that causality might run from changes in factor shares to movements in asset markets. The Panel-VAR model allows us to test for Granger causality. And indeed our analysis corroborates the bidirectional relationship between asset prices and factor shares.

Last but not least, we can relate this study to a separate strand of literature originating in financial economics. The efficient market hypothesis (EMH) suggests that the value of a financial asset is simply the discounted value of all expected future cash flows, adjusted with an appropriate risk premium (Malkiel, 1999). The theory, however, tells us very little about how those expectations are formed. A tendency of human behavior seems to be to buy high (and sell low), contrary to what the EMH predicts. Campbell and Shiller's (1988) contribution was to show that high asset prices actually predict lower future yields, at least in the medium run. However, real equity payouts are usually procyclical (Huang-Meier et al., 2015). The same procyclical behavior can be found for corporate issuance of equity and debt (Dawling and Wouter, 2011), corporate buybacks of shares (Vernimmen et al., 2014), mergers and acquisitions (Lambrecht, 2004), and corporate investment (Kothari et al., 2014). As all of these factors tend to increase capital income, they should also increase the capital share under the "ceteris paribus" condition. When it comes to housing, Leamer (2007) goes so far as to suggest that "Housing is the business cycle". Residential investment and total sales of existing dwellings display highly procyclical behavior throughout the business cycle. Figure 1 in the online appendix displays the different channels through which higher asset prices can increase capital income. Our macroeconomic analysis will not allow us to dig deeper into the various transmission mechanisms. As such, we simply investigate the overall link between asset price inflation and the capital share of GDP in aggregate.

4. Data and methodology

For the purpose of our study we combine the Macrohistory database by Jorda et al. (2016a) with the Bengtsson-Waldenström (2015) capital share database. This gives us a unique macroeconomic panel dataset comprising 17 advanced economies with time series data on an annual basis going back to 1875 for some of the countries in our panel (table 1). There are some methodological issues when it comes to the measurement of the actual capital share, most notably when it comes to the depreciation of the capital stock as well as the measurement of self-employment, which are both relatively hard to quantify. Bengtsson and Waldenström (2015) measure the gross capital share as the sum of all interest rate payments, profits, dividends, and realized capital gains divided by gross national income. The data also makes an adjustment for self-employment if possible, i.e. when data availability on a per country basis allows for such a correction to be made[1]. The database also includes the net capital share, which is defined as net capital income over net GDP. This alternative series has the advantage of being adjusted for depreciation and is available for 15 out of the 17 countries in the panel. Analyzing changes in the net factor share might be more relevant for distributional concerns since depreciation is not an income stream to any factor of production. While long-term trends in the depreciation rate are very informative, significant short-term fluctuations are quite uncommon. Consequently, the correlation between yearly changes in the gross capital share and yearly changes in the net capital share is extremely close to one, meaning that the second series does not contain any additional useful information for the purpose of our statistical analysis. However, as a robustness check, we will also compare the Bengtsson-Waldenström (2015) database with a dataset from the OECD, which contains data for total employee compensation as a share of gross value added for our 17 advanced economies from 1970 onwards. The OECD measures the gross labor share as total employee compensation by activity as share of gross value added (ILO 2015). The gross capital share is then simply defined as 100 minus the gross labor share. While this data should conceptually be the same as the gross capital share in the Bengtsson-Waldenström dataset, both series display some marked differences, showing that measurement errors in computing factor shares might be a potential

[1] Historical figures for self-employment are not always available and possibly quite inaccurate.

Table 1:
List of countries and data availability

Country	Capital share data
Australia	1911 - 2010
Belgium	1960 - 2015
Canada	1926 - 2011
Denmark	1876 - 2015
Finland	1900 - 2015
France	1900 - 2010
Germany	1891 - 2011
Italy	1911 -2015
Japan	1906 - 2010
Netherlands	1923 - 2010
Norway	1910 - 2015
Portugal	1970 - 2014
Spain	1900 - 2000
Sweden	1875 - 2015
Switzerland	1980 - 2014
UK	1891 - 2011
USA	1929 - 2010

Source: Bengtsson and Waldenström (2015) capital share database. OECD data for Portugal and Switzerland.

source of bias in studies on the functional distribution of income (Bengtsson-Waldenström, 2015).

One advantage of our panel data is that the time series is relatively long and even stretches back to the end of the 19th century, which allows us to analyze changes in the functional distribution of income over a very long time horizon and across different macroeconomic regimes, starting with the classical gold standard in the late 19th and early 20th century, followed by the more tumultuous interwar period. After World War II, the global monetary system turned to a regime of fixed exchange rates against the dollar, which itself was convertible into gold, an arrangement known as Bretton Woods. The system broke down in 1973 when the US abandoned the dollar peg to gold. The world subsequently entered the more neo-liberal growth regime with flexible exchange rates and most Central Banks in advanced economies adopted the 2% inflation target, either implicitly or explicitly, during the 1990s. A drawback of our data set, on the other hand, is that we only have annual data and that our cross-section is relatively small since it comprises only 17 high-income countries.

We estimate a Panel-VAR model for our main macroeconomic variables of interest (money, credit, asset prices, interest rate, GDP, and the functional distribution of income), which are determined endogenously within and by the macroeconomy. This approach also allows us to test for Granger causality and estimate impulse response functions for our main variables of interest. As a second approach, we also estimate a standard Panel-OLS regression, which allows us to include more macroeconomic variables as potential controls in our estimation. We try to address the issue of reverse causality between the capital share and asset price inflation by including lagged variables of the latter. We also include country and time fixed-effects to control for idiosyncratic (country-specific) shocks as well as yearly unobservable macroeconomic shocks. A drawback is that both models impose pooling restrictions across countries. We therefore disregard cross-country differences in addition to disregarding differences across time periods and different macroeconomic regimes. The first problem is more or less unavoidable because of the nature of our data. With annual data for all macroeconomic variables, estimating the model for each country separately will not give us sufficient degrees of freedom, which would decrease the efficiency and the statistical power of the analysis. The second problem can be overcome by estimating the panel model separately for the different subperiods in our data set.

5. Long-run macroeconomic trends and descriptive statistics

Before digging deeper into the main statistical analysis of the paper, we briefly summarize the main macroeconomics trends for our set of 17 advanced economies for the time period under consideration. Figures 1 and 2 depict the average gross capital share of income as well as average net capital share, respectively, for the 17 countries in question since 1875. The Bengtsson-Waldenström (2015) dataset displays the U-shaped pattern that has been previously found by Piketty (2014), with high values for the gross share above 35% of GDP both in the beginning as well as in the end of the 20th century. While there has been a more than six percentage point increase over the last few decades in favor of capital income across our panel, the long-run data shows that it is the post World War II period that was the aberration from the norm. According to Piketty (2014), it is the three major global shocks, two World Wars as well as the Great Depression, which led to an enormous amount of capital destruction across the globe. Consequently, it took several decades until capital-income ratios in advanced economies

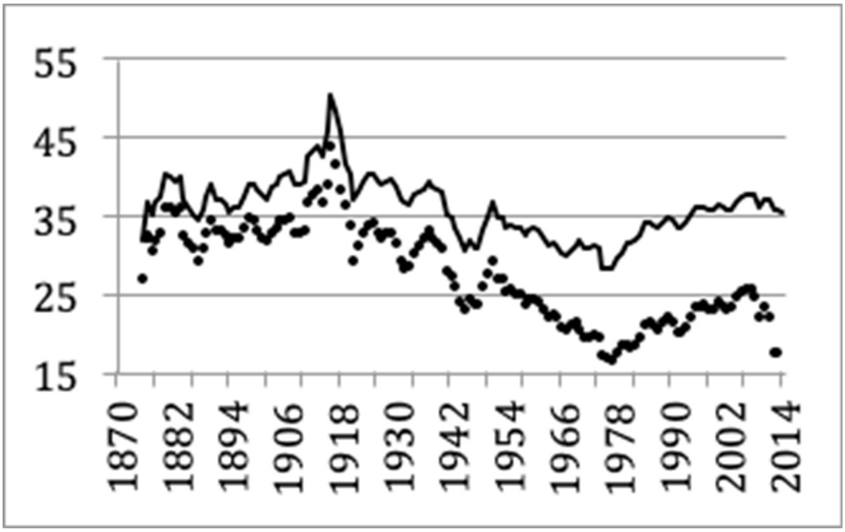


Figure 1:
Average gross and net capital share

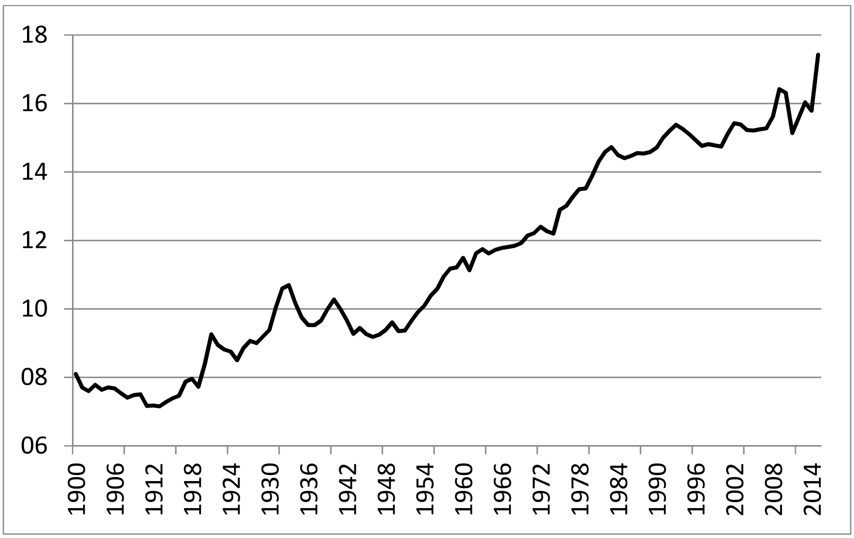


Figure 2:
Average depreciation rate as a share of GDP
Source: Bengtsson and Waldenström (2015) capital share database. This average for the net capital share does not include Portugal and Switzerland. The average depreciation rate does not include Belgium, France, Portugal, and Switzerland, for which data is unavailable.

recovered from their all-time low during 1950s. This process of capital deepening, however, has not led to a substantial decline in interest rates, thus explaining the gradual increase in the capital share over time. In terms of the following equation, the increase in the capital stock (K) thus did not depress interest rates sufficiently (r) as to lead to a reduction in total capital income over GDP (r*K/Y), which increased instead:

$$(1) \quad Y = r * K + w * L$$

Figure 1 also includes the average net capital share, defined as net capital income over net GDP, across our panel. While the net share has also seen an increase, it has not been quite as dramatic as the rise in the gross share. The obvious implication is that economy-wide depreciation has also increased in recent decades. This is supported by the Bengtsson-Waldenström (2015) data. We also display above the average economy-wide depreciation rate for 14 countries in our panel for which the data is available. One can see a steady and marked upward trend from less than 10% of GDP to more than 16% of GDP in recent years. This effect might be related to structural changes in the economy, more specifically the more intensive use of ICT (Information and communications technologies), which seem to become obsolete and outdated at a faster pace than other industrial structures (Haacker, 2010). Data from the Penn World Tables reveals that the average depreciation rate is not significantly higher than in the 1950s (Feenstra et al., 2015). However, even with a constant depreciation rate, the process of capital deepening implies a higher deprecation share of GDP. The average capital stock increased from about 300% of GDP in the postwar period to about 450% nowadays in our panel of advanced economies. A capital to income ratio of three combined with a depreciation rate of 4% implies economy-wide depreciation of 12% of GDP, whereas a capital to income ratio of 4.5 with the same depreciation rate of 4% implies economy-wide depreciation of 18% of GDP. Again, the U.S. seems to be somewhat of an outlier with the capital stock fluctuating around a more or less constant level of about 300% of GDP over the last 60 years. The process of capital deepening thus only took place in other advanced economies during the postwar economic boom, mostly Europe and Japan, leading to rapid catch-up growth to the technological leader that has been the U.S. economy for most of the 20th century (Feenstra et al., 2015). However, both gross and net investment rates have declined significantly in recent years across advanced economies, with quite obvious implications for capital accumulation and potentially even future economic growth.

6. Increasing financialization and elevated asset prices

One of the most dramatic shifts of the last few decades has been the marked rise in debt levels. While public sector debt is also elevated since the Great Recession of 2008, the global decline in nominal interest rates actually implies a lower debt burden for most advanced economies. Of more interest to us is the continuous increase in private sector leverage, which is more concerning, combined with the upward trend in asset prices, especially inflation-adjusted house prices. Figure 3 shows that loans to the private sector almost doubled, on average, from about 60% of GDP to close to 120% in the immediate aftermath of the crisis. A substantial part of this increase can be attributed to mortgage loans, which increased from a mere 20% of GDP to almost 70% of GDP in recent years. We also display the evolution of the average real house price across our sample since 1870 (figure 4). There is a remarkable stability for about a century until the late 1960s. Nominal house prices increased more or less in tandem with inflation rates, meaning that real house prices stayed relatively constant during that time period. There seems to be a structural break in the 1960s after which real house prices have increased rapidly. They almost doubled until the late 1990s, and then increased by another 60%, on average, within just two decades. The paradox of globalization is that location has become increasingly more important. Most of this can be attributed to the rising value of land, a feature that modern macroeconomic models largely tend to omit (Ryan-Collins et al., 2017). According to Lord Turner (2015), the increasing importance of location-specific real estate combined with increasing financialization has created dangerous boom and bust cycles over the last couple of decades in many advanced economies. The sharp rise in real house prices has also created a positive wealth effect and rising asset prices can serve as collateral for debt-financed consumption. Vice-versa, credit booms can lead to spectacular run-ups in asset prices, sometimes far in excess of what might be justified by fundamentals.

It is important to note though that there are enormous cross-country differences when it comes to the evolution of house prices and private sector leverage. Japan has experienced declining house prices (in real terms) since the burst of its big asset price bubble in the late 1980s. Similarly, Germany's real house prices have also stayed relatively stable in recent years. Somewhat surprisingly, it is the "social democratic" Nordic countries that have seen the strongest appreciation in real estate prices as well as the most pronounced increase in private sector leverage, closely followed by some of the Anglo-

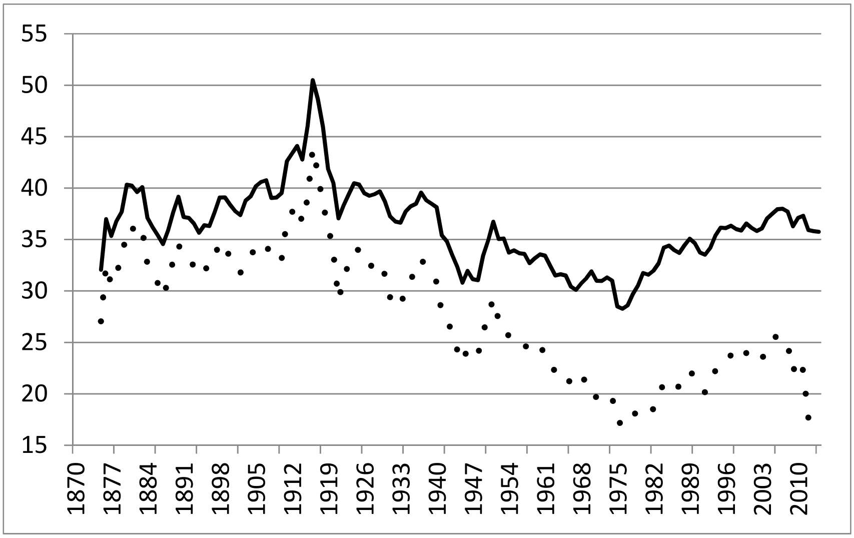


Figure 3:
Average total private sector loans to GDP ratio and mortgage to GDP ratio

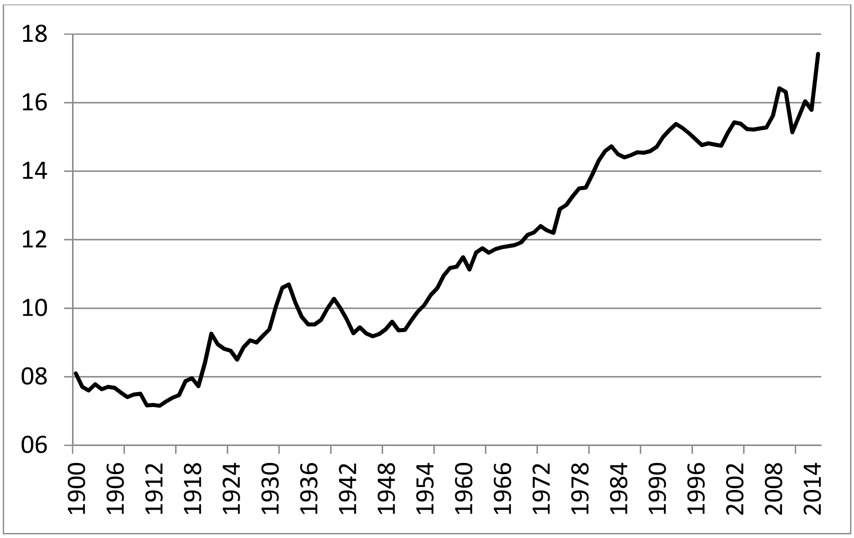


Figure 4:
Average real house prices
Source: Jorda, Schularick and Taylor (2016a) Macrohistory database

Saxon economies. Real house prices have roughly doubled in Denmark and Sweden, and more than tripled in Norway since the early 1990s. Australia has also seen its real house prices increase twofold over the same time period while appreciations in Canada and the UK were a little bit less pronounced. Compared to the aforementioned countries, the U.S. "housing bubble" looks relatively benign. In terms of private sector leverage, we can see that the countries with the strongest house price appreciations have also experienced the most marked increase in mortgage to GDP ratios. Again, the Scandinavian countries top the list with mortgage to GDP ratios exceeding 100% in Denmark while Norway and Sweden seem to be approaching that "threshold" number as well. More importantly, this represents a roughly twofold increase in mortgage to GDP ratios from the early 1980s. Similarly, Australia and the UK have also high mortgage to GDP ratios, exceeding 70% of GDP, whereas Canada and the US are still below 50%. However, the long-term secular trend in all countries in our panel is upward, with most of the action taking place since the early 1980s, the period that initiated an era of financial globalization around the world.

One can also test more formally that there has been a structural change as a result of increasing financialization for most countries in our sample since the breakdown of Bretton Woods. We use a rather simplistic approach and estimate a linear trend for the following variables of interest for each country separately: the logarithm of real house prices, the loan to GDP ratio, and the credit to GDP ratio. We then test for structural change in the time series data using the Supremum Wald test for structural break at an unknown data (the "estat sbsingle" command in Stata). The results are summarized in table 1 in appendix A. Our findings indicate that in most countries a structural break occurred in the postwar period. Our test is statistically significant at the 1% level for every country in our sample for all of those three variables in question. Countries like Australia, Canada, Norway, and Sweden, for example, have experienced considerably faster house price appreciations and private sector credit growth since the late 1980s than in the immediate postwar period. Given that a structural break has occurred, we can also estimate the trend coefficient before and after the detected break in our data. As such, real house prices were appreciating at a rate of about 6% since 1993 in Sweden compared to close to zero growth in the time period before the break. For Australia, we find a real growth rate for real house prices of close to 5% for the period after 1992 compared to only 1% beforehand. Similarly, we also detect significantly faster credit growth over that time period, especially in the Anglo-Saxon economies, and somewhat surprisingly, even more pronounced credit growth since the

1990s in the Nordic economies. As was to be expected, we also detect a very high correlation between asset prices and credit growth, supporting the notion that speculative bubbles are often debt-fueled. Both measures of credit, the mortgage to GDP ratio and total private sector credit to GDP, are highly correlated with each other, including their first differences, with the correlation coefficient exceeding 90%. This finding is unsurprising, given that mortgages nowadays make up the largest fraction of private sector credit in many advanced economies, especially in Scandinavia where extremely high house prices have been supported by a high mortgage to GDP ratio. We also measure the simple correlation between the change in real house prices and the two measures of credit, the mortgage to GDP ratio and the total private sector loan to GDP ratio, again both being calculated in first differences. We also include two lags as to measure the impact of past credit growth. We find a quite substantial positive correlation between current credit growth and changes in real house prices with the correlation coefficient exceeding 15%. The correlation with past credit growth is slightly lower but still positive (the results are summarized in table 1 and 2 in appendix C). In our Panel-VAR analysis below, we provide further support for the interaction between asset prices and credit growth. This more elaborate model also allows us to test for Granger causality, thus providing us with a more formal statistical test for the interaction between these macroeconomic variables than simple correlation coefficients. In terms of changes in the gross capital share, most advanced economies display a very similar trend in the long-run. However, there is some cross-country heterogeneity in terms of the level of the capital share. In the Anglo-Saxon economies, for example, the capital share has increased from an all-time low of about 30% in the 1980s to a high of almost 40% nowadays, thus reaching similar levels to what one could observe in the beginning of the 20th century (figure 5). The Nordic economies display a similar U-shaped pattern over the course of the last 100 years. However, the economies of Denmark and Sweden have experienced a much less pronounced increase in the capital share in recent decades. It is not entirely clear whether this difference can be attributed to structural factors, institutions, or both. Since depreciation rates do not fluctuate substantially in the short to medium run, increases in the gross share have for the most part translated in a one-to-one increase in the net capital share for the 17 advanced economies in our sample.

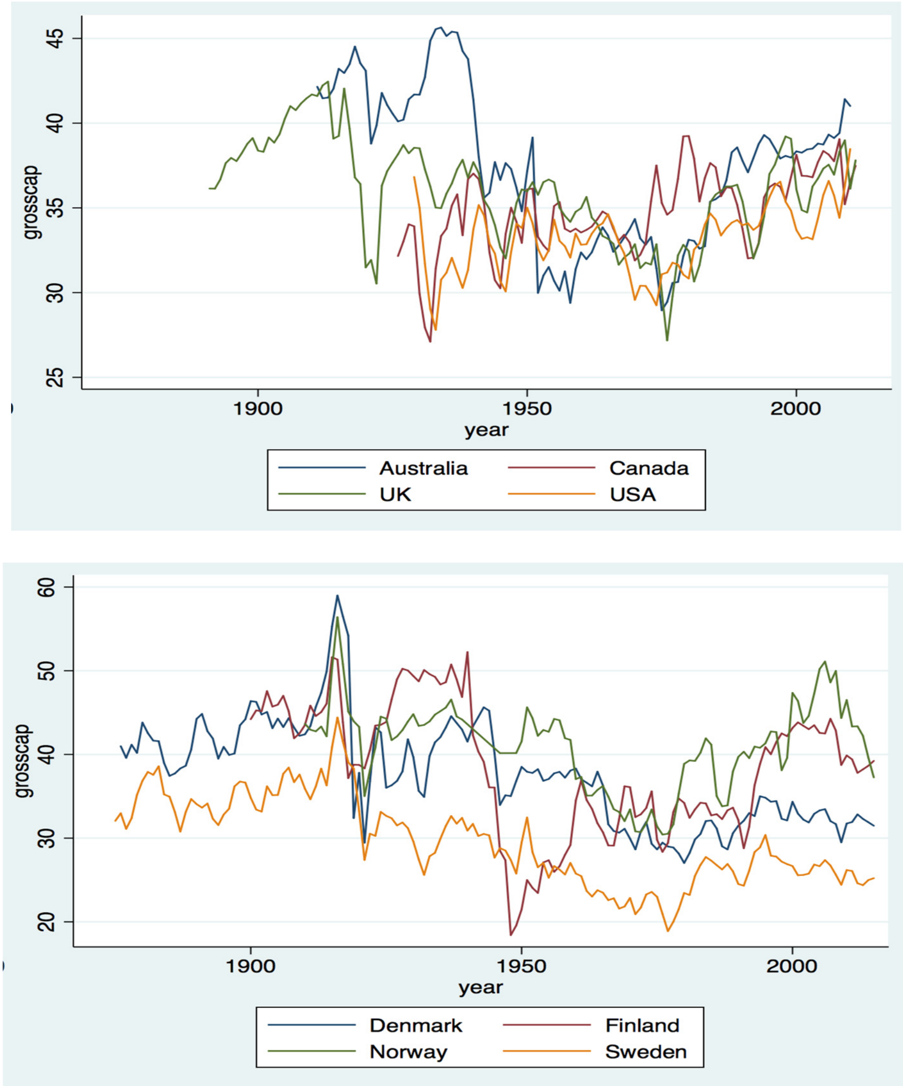


Figure 5:
Gross capital share for the Anglo-Saxon and Nordic economies, respectively
Source: Bengtsson and Waldenström (2015) capital share database

7. The Panel-VAR model

Most economists agree that money is roughly neutral in the long-run, even though there is the objection that at very high inflation rates velocity increases as well (De Grauwe and Polan, 2005). However, a large body of academic literature supports the notion that monetary shocks have real effects in the short-run. Friedman and Schwartz's (1963) account of the Great Depression shows that monetary policy failure can mostly explain the economic downturn of the 1930s. Romer and Romer (1989) find that unexpected monetary policy shocks have large and persistent effects on output and employment. More recently, a number of studies have examined in more detail the monetary transmission mechanism. There is no doubt that monetary policy also affects asset prices in the short to medium-run via adjustments of the key policy rate (Mishkin, 2007b). Furthermore, many studies confirm the positive interaction between credit booms and asset price bubbles, particularly real estate (Jorda et al., 2015). Moreover, household debt has increased sharply in many advanced economies, mostly a result of rising mortgage to GDP ratios, with important implications for financial stability as the private sector becomes more and more leveraged (Jorda et al., 2016b). More recently, a number of studies have confirmed that monetary policy shocks also affect inequality. Coibion et al. (2012). for example, show that contractionary monetary policy shocks can have a significant impact on labor income inequality. Based on these macroeconomic interactions, we follow the approach by Goodhart and Hofmann (2008) and estimate the following Panel-VAR equation for our macroeconomic system:

$$(2) \quad Y_{i,t} = A(L)Y_{i,t} + \varepsilon_{i,t}$$

where $Y_{i,t}$ is a vector of endogenous variables and $\varepsilon_{i,t}$ is a vector of errors. A(L) is a matrix polynomial in the lag operator whose order is determined by the Akaike information criterion considering orders up to three. The vector of endogenous variables comprises eight key variables of interest: the log difference of real GDP (Δy), the log difference of the consumer price index (Δcpi), the level of the short-term interest rate (i), the log difference of nominal stock prices $\Delta stock$, the log difference of nominal house prices (Δhp), the log difference of nominal broad money (Δm), and the log difference of nominal private credit (Δc). Unlike Goodhart and Hofmann (2008), we also include the log difference of nominal stock prices ($\Delta stock$)

and the gross capital share (cap share) in our model. The vector $Y_{i,t}$ is therefore given by:

$$(3) \qquad Y = [\Delta y, \Delta cpi, \mathrm{i}, \Delta stock, \Delta hp, \Delta m, \Delta c, cap\ share]$$

Our model thus comprises some key monetary variables (inflation, nominal interest rates, money, and credit), asset prices (nominal stock prices and house prices) as well as two real outcomes (real GDP and the capital share). We can thus determine the interaction between monetary policy, asset prices, and the functional distribution of income.

The advantage of the Panel-VAR model is that it greatly increases the efficiency and the statistical power of the analysis. Estimating the eight-dimensional VAR model on a country level is simply infeasible given that we do not have enough data points, i.e. the model would suffer from insufficient degrees of freedom. However, a drawback of the Panel-VAR approach is that it imposes the pooling restriction. We therefore disregard cross-country differences in the estimated dynamic relationship by design. On the other hand, adopting a panel framework in a macro-analysis can help to uncover systematic dynamic relationships, which might otherwise be obscured by idiosyncratic effects on the country level (Gavin and Theodorou, 2005). Usually, time dummies are included in such studies if the cross-section is large. However, in our case, the cross-section is rather small while the time dimension is very large. Including time dummies would thus come at a great cost of efficiency and statistical power (Goodhart and Hofmann, 2008). A common problem one encounters in time series data is spurious correlation because of the existence of unit roots in the data. That is why most of the variables of interest, with the exception of the capital share and the nominal interest rate, are expressed in logarithmic first differences. Before estimating the model, we test whether our variables of interest are stationary. Using the Im-Pesaran-Shin unit-root test (Im et al., 2003) for heterogeneous panels, we do find strong evidence that our variables are stationary across cross-sectional units (we can reject the null hypothesis of unit roots at the 1% level).

The Panel-VAR model relies on the so-called "Helmert procedure", an estimation technique suggested by Arellano and Bover (1995). Pooling data imposes the restrictions that the underlying structure is the same for each cross-sectional unit. One way to overcome the restriction is to introduce fixed effects, which allow for individual heterogeneity. However, mean-differencing would create bias since the fixed effects are correlated with the regressors due to lags of the dependent variables. The "Helmert procedure" is a transformation that only removes the forward mean. It thus preserves the orthogonality between transformed variables and lagged regressors, which can be used as instruments to estimate the coefficients by System GMM (Love and Zicchino, 2006). This method also has the advantage that estimation is feasible with an unbalanced panel, as is the case with our data.

The Panel-VAR model also allows us to test for Granger causality. Moreover, we can estimate impulse response functions, which describe the reaction of one variable to the innovation of another variable, whilst holding all other shocks equal to zero. We recover the orthogonalized shocks of the system by using a simple Cholesky decomposition (Goodhart and Hofmann, 2008) and construct 95% confidence intervals using Monte-Carlo simulations. The ordering of the variables in our system is given by equation (4). According to Love and Zicchino (2006), the particular ordering of the variables is quite important as the variables that appear earlier in the system are more exogenous while the variables that appear later are more endogenous: The identifying assumption is that the variables that come earlier in the ordering affect the following variables contemporaneously, as well as with a lag, while the variables that come later affect the previous variables only with a lag (Love and Zicchino, 2006). We follow closely the approach used by Goodhart and Hofman (2008) who argue that the ordering of the first three variables (GDP growth, inflation, and interest rates) is standard in the monetary transmission mechanism. The ordering of the remaining variables is somewhat arbitrary. Credit was ordered after money because it is more plausible to assume an immediate effect of a change in the money stock on credit rather than vice-versa (Goodhart and Hofmann, 2008). Finally, the capital share is the variable that is the most endogenous in our system. Robustness checks, however, suggest that the particular ordering of the variables does not have a substantial effect on our results.

8. Empirical results

Following Eichengreen (1998), we split our data into several subperiods, which correspond to different global macroeconomic regimes. The period from 1875 to 1914 is that of the classical gold standard when all major currencies were pegged to the price of gold and thus also fixed with respect to each other. The subsequent period from 1914 to 1944 is the tumultuous interwar period. While some countries like the UK left the gold standard to finance their World War I efforts, they decided to join the currency arrangement again after the end of the war. It is now widely accepted that the interwar gold standard led to the global Great Depression in the early 1930s because of the deflationary bias that was baked into the system. As global gold demand would eventually outstrip global gold supply, commodity prices would have to fall worldwide to reach equilibrium. One by one countries decided to opt out and abandon the peg to gold in the early 1930s as the necessary deflation and the associated depression turned out to be too costly. The Great Depression also culminated in the rise of fascist regimes across Europe, a consequence of mass unemployment, and the horrors of World War II (Eichengreen, 1998). The postwar period was characterized by the Bretton Woods agreement of fixed exchange rates. All major currencies were pegged to the dollar, which itself was convertible at a fixed price into gold. The Bretton Woods regime from 1944 to 1973 was characterized by relative economic stability and high growth rates across advanced economies. However, the US had to run persistent current account deficits to supply the world with the necessary dollar reserves. The combination of loose fiscal and monetary policy during the Vietnam War efforts led to high rates of inflation and the pegged exchange rate agreement broke down once the dollar's convertibility into gold was questioned (Eichengreen, 1998). The period from 1973 to 2013 is known as the neoliberal growth regime with flexible exchange rates. Since the early 1990s, most Central Banks across advanced economies have adopted some kind of formal or informal inflation targeting regime, usually defining price stability as being consistent with an inflation rate of 2%. Some authors argue that modern Central Banking has greatly contributed to the macroeconomic stability after 1980, a period that is also known as the Great Moderation (Bernanke, 2004).

We estimate equation (2) with System GMM, using lags one to three as instruments in the estimation procedure. We choose to include only one lag of the endogenous variables in our analysis based on the Akaike and Schwarz information criteria. We estimate the system for the entire panel data set from 1875 to 2013 and four different subsamples corresponding to the global macroeconomic regimes mentioned above. Because we only have limited data points for the late 19th century, we have to bundle the period of the classical gold standard and the tumultuous interwar period together, leading to one subsample from 1875 to 1944. We also estimate the model for the entire postwar period from 1945 to 2013. Finally, we split up the sample into the Bretton Woods period from 1945 to 1973 and the period of flexible exchange rates from 1974 to 2013.

We test all of the Panel-VAR models for stability, i.e. that the modulus of each Eigenvalue is less than one. An unstable Panel-VAR usually implies that a shock to the system would never die out, but rather explodes (Abrigo and

Love, 2016). We find that the stability of the Panel-VAR model is satisfied for all three subperiods after World War II. On the other hand, we find that one of the Eigenvalues is larger than one when we estimate it for the entire time period from 1875 to 2013 as well as for the subperiod of the classical gold standard (from 1875 to 1944), meaning that we have to proceed with caution in interpreting the obtained impulse response functions because the system suffers from instability. This is most likely the result of a number of extreme outliers in our data set, especially during the interwar periods, which contains the German hyperinflation of the early 1920s, for example. Italy and Japan are two other countries in the dataset that suffer from hyperinflationary episodes during the World War II period. These and other outliers during the tumultuous early 20th century are probably extreme enough to introduce instability in the system.

Table 3 and table 4 in the online appendix summarize the estimation results from our Panel-VAR analysis and the results from the Granger causality tests, respectively. Our findings are generally in line with prior expectations. We find a positive correlation between past money growth rates and subsequent asset price growth, especially for stock prices but also for house prices. This result seems to be robust as it holds across the different subperiods in our panel. In terms of Granger causality, we find that the money growth rate Granger causes asset price growth, but not necessarily vice-versa. However, for most periods we do find a statistically significant two-directional Granger causality at the 1% level between money growth and stock price growth, but not necessarily between money growth and house price appreciations.

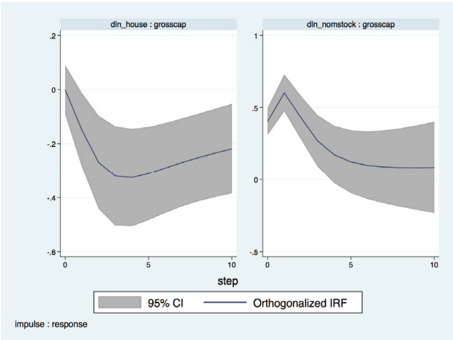
We also find a positive relationship between credit growth and asset prices. More specifically, past asset price growth seems to predict subsequent credit expansions. This result is intuitive insofar as it rests upon the aforementioned wealth effect (Mishkin, 2007a). As the value of the market portfolio rises in aggregate, consumption tends to increase as well since consumers are wealthier than before. Moreover, part of the consumption can be debt-driven as higher asset prices can also serve as a collateral for consumer credit. In terms of Granger causality, we find a two-directional relationship between credit growth and house prices. This result is also statistically significant, and the relationship can be confirmed across different time periods in our panel. Again, this finding is not very surprising given that a substantial part of private sector credit consists of mortgages.

When it comes to the capital share, we find a positive relationship with private sector credit growth. This relationship is very robust across all time periods and Granger causality between the two variables can be confirmed at the 1% level in both directions. The effects of GDP growth, inflation, and interest rates on the capital share, however, seem to be time-varying and highly dependent on the macroeconomic regime in question. Inflation is mostly negatively correlated with the capital share and this result is highly statistically significant, with the exception of the last subperiod in our analysis, which corresponds to the emergence of the 2% inflation target across advanced economies. In terms of asset prices, we do find the expected positive effect between past stock price growth and the capital share. The result seems to be robust since it holds across all time periods in our analysis. In terms of Granger causality, we find strong evidence that stock price growth Granger causes the capital share. When it comes to housing, however, we find a negative correlation between house price appreciation and the capital share. Moreover, the result is statistically significant and robust across our different subsamples. Since this effect is contrary to our expectations, we have some difficulty explaining this particular finding.

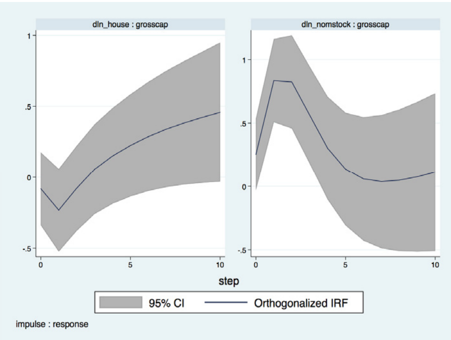
Last but not least, we also estimate orthogonal impulse response functions using Monte Carlo simulations with 200 draws for the different Panel-VAR models we have estimated above. The impulse response functions are capturing the effect of a unit shock to stock price growth on the capital share, or alternatively a unit shock of house price growth on the capital share. Figure 6 displays the results from an innovation of asset prices on the capital share for the different time periods in question. A one standard-deviation shock to nominal stock price growth positively affects the capital share, but the effect dies out after about two to four time periods, meaning years in our case. The cumulative impact of an innovation of stock price growth on the capital share is about 0.6 to 1.5 percentage points, depending on the subsample under consideration. For the period of Bretton Woods, we find a stronger increase in the gross capital share in response to a stock price growth innovation whereas for the period of flexible exchange rates post 1973 we only find a cumulative increase of about 0.6 percentage points in the capital share over the subsequent two years. Somewhat surprisingly, our results indicate a negative response of the capital share to an innovation in house price growth. Moreover, this finding seems to be consistent across different time periods. This result is hard to explain and also contrary to our

Figure 6: Impulse response functions of asset price growth on the gross capital share (House prices left, stock prices right)

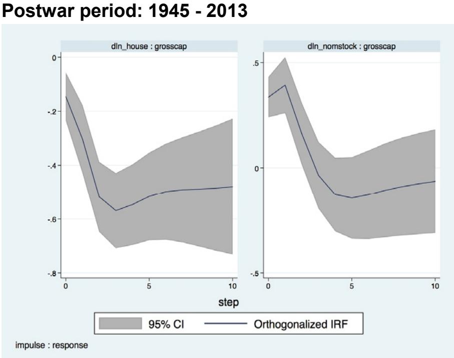
Entire sample: 1875 - 2013



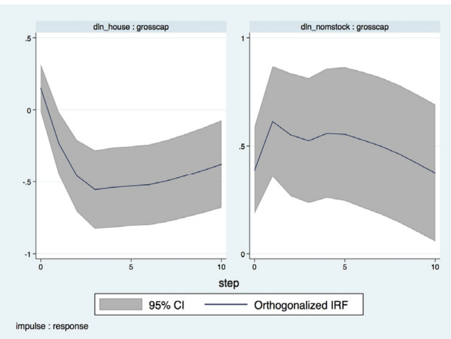
Gold standard & WWII period: 1875 - 1944



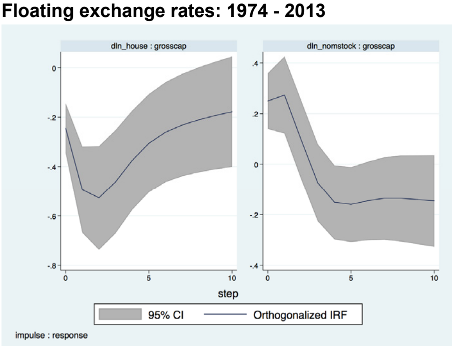
Postwar period: 1945 - 2013



Bretton Woods: 1945 - 1973



Floating exchange rates: 1974 - 2013



Source: Author's calculations

expectations. When it comes to the other variables in the system, we find a consistent positive effect of an innovation to real GDP growth on the capital share within the subsequent couple of years across all time periods in our sample. The inflation rate, on the other hand, produces a negative shock to the capital share.

We also estimate the same Panel-VAR specification using the Bengtsson-Waldenström (2015) data for the net capital share as a robustness check instead of using the gross shares. Just as before, the Panel-VAR model is unstable when we estimate it for the entire time period and the period of the gold standard before 1944. However, the model displays stability for all three subperiods of the postwar era. The impulse response functions are very similar to the ones we found just above, thus providing a robustness checks to our findings. An innovation to stock price growth results in a cumulative increase of the net capital share of about one to 1.5 percentage points within the next two to four years for the postwar period. Again, the effect seems to be somewhat stronger during Bretton Woods when an innovation to stock price growth results in a subsequent increase of the net capital share of about 1.3 percentage points within the next three years compared to an increase of one percentage point over the subsequent two years for the period of flexible exchange rates post 1973.

Summing up, the most important finding of our Panel-VAR analysis is that we can confirm the expected positive correlation between stock prices and the capital share. More specifically, a one standard deviation shock to nominal stock prices leads to a cumulative increase in the capital share of about 0.6 to 1.5 percentage points within the subsequent two to three years. The exact magnitude of the effect is somewhat dependent on the subperiod under consideration. Furthemore, the effect is relatively similar for the gross measure and the net measure of the capital share. Somewhat surprisingly, the Bretton Woods era is characterized by a larger capital share sensitivity with respect to stock price growth than the period of flexible exchange rates after 1973. We cannot explain why innovations to house prices produce a negative effect on the capital share across our different specifications.

9. The Panel-OLS model

In the spirit of Stockhammer (2013), we also estimate a Panel-OLS model to examine the main determinants of the functional distribution of income. The advantage of the Panel-OLS model compared to the Panel-VAR approach is that we can incorporate more control variables into the analysis. More specifically, the capital share is a function of variables that measure economic growth and technological change, the business cycle, globalization, and financialization:

(4) Capital share = f(growth, business cycle, globalization, financialization)

This approach is consistent with the political economy and power resource theory approach where the functional distribution of income is determined as a result of a bargaining process between capital and labor instead of being the natural outcome of market clearing processes, as emphasized by the neoclassical approach (Stockhammer, 2013). We thus estimate the following Panel-OLS model that is supposed to capture the relationship described by equation (4):

$$(5) \quad capital\ share_{i,t} = A_i + \beta_1 \Delta house\, price_{i,t} + \beta_2 \Delta stock\, price_{i,t} + X'\beta_{3_{i,t}} + t * A_i + t + \delta_t + \varepsilon_{i,t}$$

where A_i are the country fixed-effects, δ_t are the time fixed-effects, and $X'_{3_{i,t}}$ represents the vector of control variables based on the academic literature summarized above, mostly following the approach by Stockhammer (2013). In contrast to the Panel-VAR model, we now also include time fixed-effects (the time dummy variable δ_t) in this estimation method to control for unobserved yearly macroeconomic shocks. However, we must take into consideration that this choice might come at a cost though. As our time dimension is large, including yearly dummy variables reduces the power of the estimation at hand by significantly increasing the degrees of freedom. Last but not least, we also include a time trend variable, which we also interact with country dummies, to control for general as well as country-specific long-run secular trends in our data[2].

2 We first estimated equation (5) without including trend variables and plot the residuals for each country over time. For many countries, the residuals are non-stationary, thus implying an obvious misspecification in our regression. After including country-specific trend variables, the residuals for each country become stationary. Since a simple country-specific linear trend seems to resolve the misspecification, especially when we consider the subsamples instead of running the regression for the entire time period from 1875 to 2013, we do not include any quadratic or other non-linear trends.

In terms of the vector of control variables, we have expressed most variables in first differences (i.e. growth rates) to make them stationary in order to avoid spurious regressions. We use real GDP growth as a measure of technological change. We control for the business cycle by estimating the output gap and we also include nominal interest rates and the rate of inflation. Money growth and credit growth are our two proxy variables for financialization. We use trade openness as a proxy variable for globalization where trade openness is defined as the sum of exports plus imports divided by total GDP. We also include government expenditures as a share of GDP. Last but not least, we use trade union density as measure of union power in our last specification, which uses the OECD data for the capital share from 1970 onwards. Data limitations do not allow us to include union density and the unemployment rate for the entire time span. Regardless, unions were still relatively weak in the beginning of the 20th century. Trade union power rose slowly over the course of the century to reach a peak in the postwar era, thereafter entering a period of steady secular decline starting in the early 1980s with the liberalizations initiated during the Reagan and Thatcher era (Western, 1995).

We calculate the output gap for real GDP using the standard Hodrick-Prescott (HP) filter (Hodrick and Prescott, 1998) and a smoothing parameter of $\lambda = 6.25$. There is some debate on the validity of the HP filter. More specifically, the estimated cycle component will depend on the smoothing parameter, which is chosen somewhat arbitrarily. For annual data any value of λ between 6.25 and 100 might be appropriate. We use the lower bound, which was suggested as appropriate for annual data by Ravn and Uhlig (2002). Some other well-known problems associated with the HP filter are that it performs poorly in the beginning as well as the end of the data (Hamilton, 2017). Furthermore, applying the HP filter to real GDP, we find a large positive output gap for the US for the time period before the Great Depression and a somewhat smaller than expected negative output gap during the Great Depression itself. This literally suggests that potential GDP was far above trend in the late 1920s, which might be somewhat unreasonable. It seems more realistic to assume that GDP was actually close to trend before the Great Depression and that the subsequent negative output gap was of similar magnitude to the actual decline in real GDP[3].

[3] More recently, Hamilton (2017) has suggested an alternative approach to find the cyclical component of a time series variable x_t. He proposes to regress x_{t+h} (with h usually being equal to 3) on up to four lags of x_t. The residual of such a regression are then equal to the cyclical component of the variable x_t. However, when we apply such an approach to real GDP we find unusually large cyclical components with output gaps that are unrealistically

As before, we estimate the regression for the entire time period as well as for the various subsamples we have previously considered. Table 1 in appendix B displays the baseline regression, including all the control variables but without incorporating either stock price growth or house price growth for now. The results we obtain are similar to what is usually found in the academic literature. Real GDP growth is positively correlated with the capital share and also statistically significant at the 1% level across all the five subperiods for which we run the regression. The result thus seems to be extremely robust as it holds across various time periods. Moreover, the effect seems to be more pronounced in recent decades as the coefficient is larger in size in estimation (5) for the period post Bretton Woods, with an increase of real GDP growth by 1% being associated with an increase in the capital share of about 0.4 percentage points. The positive relationship might be indicative of the procyclical behavior of markups that was found by Nekarda and Ramey (2013). Moreover, Stockhammer (2013) finds a similar result and argues that this is to be expected as wages, in general, are more sticky than prices. Our measure for the output gap, as estimated with the common HP filter, on the other hand is negatively correlated with the capital share. However, the coefficient is mostly insignificant across our various specifications. It should be noted though that real GDP growth and the output gap are highly correlated (0.56%), meaning that the two variables are capturing to some extent the same effect, namely the business cycle. It is only during the post Bretton Woods period that the output gap coefficient becomes larger in size and also statistically significant, potentially capturing the effect that a high pressure economy is beneficial for the wage share, as argued by Growiec et al. (2015), who find that fluctuations in the US wage share are pro-cyclical in the medium run. The effect of the short-term interest rate on the capital share seems to be time-varying and dependent on the macroeconomic regime. While the relationship is positive and statistically significant during the period of the gold standard, for example, the relationship turns out to be negative in the period Bretton Woods. However, for other subsamples the coefficient turns out be statistically insignificant. Credit growth and money growth are also mostly insignificant in explaining movements in the capital share. The rate of inflation is statistically significant across all subperiods. The coefficient is negative for all subperiods with the exception of the time period of Bretton Woods.

big and largely exceed those obtained with the HP filter. Consequently, for all of its drawbacks, we use the HP filter, which remains one of the most commonly applied techniques in empirical macroeconomic studies (Hamilton, 2017).

Inflationary pressures thus seem to be associated with a decline of the capital share across various macroeconomic regimes, potentially indicating that a high- pressure economy might be beneficial for the wage share. However, we do not have a very good explanation for why this relationship does not hold for the postwar period of Bretton Woods. The variable trade openness has the expected positive sign and is statistically significant across all time periods, as was to be expected, with an increase in trade openness by 10% being associated with an increase in the capital share of about 0.7 to 1.4 percentage points. Stockhammer (2013) argues that globalization depresses the wage share because it reduces the bargaining power of labor, as workers have to compete with foreign competition. It is thus interesting that we detect a very large effect of trade openness on the capital share not only during the recent period of globalization after 1973, but also during the first wave of globalization around the turn of the 20th century. Government expenditures are consistently negatively correlated with the capital share and this result is statistically significant at the 1% level across our various subsamples. Again, this result is consistent with the literature and was to be expected since the government sector does not contain a profit share (Stockhammer, 2013).

In specification 2 (table 2 in appendix B), we now include nominal stock prices and nominal house prices in first differences, i.e. growth rates, as well as two lagged variables of the first difference. The appropriate lag order was chosen based on the Akaike information criterion considering lags of up to two time periods. We do not consider more than two lags because doing so would come at the cost of reducing our number of observations by a substantial amount.

We find that stock price growth is consistently positively correlated with the capital share and this result is also statistically significant at the 1% level. Moreover, this effect can also be found for the lagged variables that we have included in order to address the issue of reverse causality between the capital share and asset prices. The idea is that current values of the capital share cannot cause past values of asset price growth whereas past asset booms might very well lead to subsequent changes in the functional distribution of income. The positive relationship between stock price growth and the capital share is very robust across various subsamples. Not only are the coefficients statistically significant, but the economic effect seems to relatively large in size as well. An increase in stock prices by 10% is associated with an increase in the capital share of about 0.1 to 0.3 percentage points, depending on the time period under consideration. The two lagged variables for stock prices have roughly the same economic effect on the capital share and are also statistically significant. It is interesting to note that the effect is existent for all time periods, with the exception of the Bretton Woods period when capital mobility was extremely limited and exchange rates were pegged to the dollar. Asset price booms were in general more muted and the international transmission mechanism was more benign during that time period. Both financialization as well as increasing globalization only started to reemerge after the end of Bretton Woods, not only leading to a higher synchronization of the international business cycle but also to larger comovement of international asset prices (Jorda et al., 2018). Consequently, one might also expect a lower elasticity of the capital share with respect to stock price booms if the latter were more muted globally during the time period of Bretton Woods. It is interesting to note that the stock price growth coefficient is the largest during the subperiod from 1875 to 1944, which includes the "Roaring twenties", certainly a period that was chararacterized by an economic expansion combined with booming asset prices and relatively high capital mobility between the advanced economies in our sample. Nominal house price growth, on the other hand, seems to be insignificant across all the subperiods under consideration. Similar to our Panel-VAR model, we cannot detect a positive relationship between the capital share and house price appreciation in our sample.

In specification 3 (table 3 in appendix B), we include three-year moving averages for the growth rate of nominal stock prices and house prices instead of annual growth rates. Again, we do not find a statistically significant positive relationship between house price changes and the capital share. Using the moving average instead does not significantly alter the relationship between stock price growth and the capital share. The coefficient is statistically significant at least at the 5% significance level across all subperiods, with the time period of Bretton Woods again being the notable exception. However, the economic effect now also appears to be slightly stronger. An increase of 10% in the 3-year moving average of nominal stock price growth is now associated with an increase in the capital share of about 0.3 to 0.8 percentage points, depending on the time subperiod under consideration.

10. Bubble indicators

As noted before, there is a large academic literature on the interaction between asset price bubbles and debt cycles (Jorda et al., 2016). Reinhart and Rogoff (2009), for example, document that financial crises and asset price bubbles have occurred in much greater frequency over the last two centuries than what is commonly assumed, both across advanced economies and especially in emerging markets. While in the last section we simply examined the interaction between asset price growth in general and the capital share, we now also test for the significance of financial bubbles by using three different indicators that measure asset price growth above a certain trend.

First, we examine whether it is asset price growth above trend that matters. In specification (4), we thus use the first difference of the growth rate of asset prices, which can be interpreted as an acceleration of the growth rate (table 4 in appendix B). That is because the second difference of a variable is conceptually similar to the second derivative. Our results suggest that an acceleration in nominal stock price growth is mostly insignificant across all time periods. On the other hand, there now seems to be a positive relationship between the capital share and the first difference in house price growth as well as its first lag for the postwar period from 1945 to 2013. While the result does not seem to be existent for the immediate postwar period after World War II during Bretton Woods, the positive relationship emerges again for the last period from 1973 onwards. We have shown above that real house prices have stayed fairly constant in many advanced economies for almost one century, and for that reason it might ultimately be not surprising that we cannot detect a positive relationship between house prices and the capital share. Over the last few decades, however, most advanced economies have experienced significant house price appreciations combined with higher indebtedness and also higher leverage. We interpret the results from specification (4) as evidence for the fact that accelerations in house price growth are positively correlated with the capital share, at least for the period from 1973 onwards.

Second, we also apply the Hodrick-Prescott filter (HP) to estimate the cyclical component for stock prices and house prices in order to determine aberrations from the long-run trend. Similar to GDP, we use the smoothing parameter of $\lambda = 6.25$ and then calculate the gap between the actual value and its the long-run trend. We can use this value as a "bubble indicator". Large positive deviations between actual asset prices and the estimated long-run trend can be indicative of booms, maybe driven by speculative behavior. The results of this specification (table 5 in appendix B) suggest that stock price growth above trend, as estimated by the HP filter, is positively associated with the capital share. The coefficient, however, is only statistically significant for some of the subperiods in our sample. More specifically, the positive relationship between above-trend stock price growth and the capital share only seems to emerge in the postwar period. We do not find in general a positive relationship between above-trend house price growth and the capital share.

Third, we also calculate the mean as well as the standard deviation of nominal stock price growth and nominal house price growth for all countries in our database. We then standardize each year's growth rate by calculating the deviations from the mean in terms of one standard deviation. This estimator is thus supposed to be another indicator of above-trend asset price growth, i.e. financial bubbles. We find a strong statistical relationship between above-trend stock price growth and the capital share across all subperiods, with the exception of the Bretton Woods period (table 6 in appendix B). An increase by one standard deviation in stock price growth is generally associated with an increase in the capital share by about 0.3 to 0.8 percentage points. The effect is the most pronounced for the period from 1875 to 1944, followed by the period of floating exchange rates after 1973. On the other hand, we cannot detect such a statistically significant effect for the house price variable.

Last but not least, we use the OECD capital share data instead as a robustness check for our results (table 7 in appendix B). The OECD data defines the capital share as one hundred minus total employee compensation as share of gross value added, including an adjustment for the labor income of the self-employed (ILO, 2015). The correlation between the OECD capital share data and the gross capital share from the Bengtsson-Waldenström database (2015) is about 30% while the correlation between the first difference of the two variables is significantly higher with a value of about 80%. The OECD data starts in 1970 and thus only covers our last subsample for the period post Bretton-Woods. We now estimate all the previous specifications using the OECD data instead (table 6). However, we also include the unionization rate and the unemployment rate as additional control variables. Labor unions affect the bargaining power of workers, as argued by Fichtenbaum (2011), and are thus expected to have a negative effect on the capital share. The unemployment rate is an additional cyclical variable for labor market slack in general and is thus also being associated with labor's relative bargaining power. Our findings based on the OECD data are in general very similar to what we have found based on the Bengtsson-Waldenström (2015) database, thus providing us with a robustness check for our analysis above. GDP growth remains statistically significant across all subperiods and is positively correlated with the capital share. Trade openness and the unemployment rate are also positively correlated with the capital share. The output gap is negatively correlated with the capital share, but not always statistically significant. As before, government expenditures are negatively affecting the capital share and the unionization rate also has the expected negative sign and is statistically significant across the various specifications. In terms of asset prices, the effect of stock prices on the capital share is still statistically significant. However, the effect seems to be somewhat smaller than in the previous regressions using the Bengtsson-Waldenström data. We can also confirm the finding that stock price growth above trend, as estimated by the HP filter or in terms of standard deviations from the mean growth rate, is positively correlated with the capital share. More importantly though, the three-year moving average of the house price growth variable now also has the expected positive sign and is statistically significant at the 1% level. The coefficient seems to be relatively large too, with an increase of nominal house price growth being associated with an increase in the capital share of about 0.35 percentage points whereas the effect for stock prices is somewhat smaller, about 0.2 percentage points only. House price growth above trend, on the other hand, does not seem to have an effect on the capital share.

Summing up, the OECD data confirms our previous findings as we can detect the aforementioned positive relationship between stock price growth and the capital share. Moreover, we now also find a statistically significant positive relationship between house price appreciations and the capital share, but only in one of the specifications.

11. Robustness check

As a robustness check, we also re-estimate every single regression using clustered standard errors by country. This approach is used to address heteroscedasticity and autocorrelation in the standard errors. The latter problem is especially likely to exist in our analysis given the nature of our data, a panel dataset with a large time series dimension. However, sometimes the cure might actually be worse than the disease, as suggested by Angrist and Pischke (2008). They argue that clustering might actually not be the right approach, especially if the number of clusters is small, as it is in our case with only 17 countries in the panel. Regardless, clustering the standard errors does not change the size of the coefficients in the estimation, but simply increases the size of standard errors. This more conservative approach thus increases the likelihood of rejecting the null hypothesis. While some of the variables like trade openness now become statistically insignificant, even at the 10% level, nominal stock price growth remains statistically significant throughout most specifications, thus providing additional power to our statistical analysis.

12. Quantifying the effects

Our results from above suggest a significant positive relationship between stock price growth and the capital share. However, the exact magnitude of the effect is hard to quantify since the long-run impact will differ from the short-run impact. Table 2 below shows that stock price growth in most countries has in general been above the historical average since the 1980s, a result of increased financialization across advanced economies. This is true both for nominal as well as inflation-adjusted asset prices. While the Panel-OLS model only estimates the short-run effect, our Panel-VAR model allows us to be more specific about the long-run relationship between asset price growth and the capital share. The estimated impulse response function suggest that a one standard deviation shock to stock price growth has a cumulative positive effect of about 0.6 to 1.5 percentage point on the capital share over a time period of about two to three years. As a final note of caution, one should be aware though that all the estimated coefficients, both in the Panel-VAR model as well as in the Panel-OLS specification, respresent average marginal effects across our panel. As our model does not include country-specific estimators, country heterogeneity is hidden by assumption. However, as argued by Gavin and Theodorou (2005), the panel framework allows us to increase the number of observations and to reveal systematic macroeconomic relationships that might be hidden by idiosyncratic effects on the country level.

All the Scandinavian economies, for example, have experienced nominal stock price growth in excess of 10% since the 1980s, which is well in excess of the long-run historical average. The cumulative return amounts to several standard deviations in excess growth. Taking our short-run coefficients seriously, this could explain up to several percentage points of the increase in the capital share in the countries that have experienced above average stock price growth in recent decades.

Table 2:
Asset prices, summary statistics

	Nominal house price growth		Nominal stock price growth			
	1871 - 2013		1871 - 2013		1980 - 2013	1990 - 2013
Country	**Mean**	**Std. deviation**	**Mean**	**Std. deviation**	**Mean**	**Mean**
Australia	4.64%	10.08%	4.64%	10.08%	7%	4.9%
Belgium	4.93%	9.84%	4.93%	9.84%	6.7%	3.8%
Canada	5.00%	7.42%	5.00%	7.42%	6.2%	5.1%
Denmark	3.86%	7.54%	3.86%	7.54%	10.1%	7.5%
Finland	9.05%	17.11%	9.05%	17.11%	10.3%	5.3%
France	6.59%	8.28%	6.59%	8.28%	5.6%	3.4%
Germany	3.72%	10.95%	3.72%	10.95%	8.7%	7%
Italy	8.14%	12.58%	8.14%	12.58%	7.5%	1.7%
Japan	11.24%	21.21%	11.24%	21.21%	2.7%	-3.4%
Netherlands	3.13%	9.15%	3.13%	9.15%	6.4%	4.2%
Norway	4,17%	8.43%	4,17%	8.43%	12.7%	10.1%
Portugal	3.13%	6.13%	3.13%	6.13%	10.1%	1.6%
Spain	9.28%	11.13%	9.28%	11.13%	8.8%	4.5%
Sweden	3.65%	7.57%	3.65%	7.57%	12.2%	7%
Switzerland	3.14%	5.58%	3.14%	5.58%	6.5%	6.3%
UK	4.80%	9.42%	4.80%	9.42%	8%	4.6%
USA	3.42%	7.54%	3.42%	7.54%	8.3%	6.9%

Source: Author's calculations

13. Interpretation of results and policy implications

Using two separate models, the Panel-VAR estimation as well as a more standard Panel-OLS specification, we find conclusive evidence for the interaction between asset price growth and the capital share of income. Our results thus suggest that high asset price valuations might not only increase wealth in aggregate, but also affect the functional distributional of income by increasing the capital share of GDP. Across various specifications, we detect a statistically significant and also economically significant effect of asset price growth on the capital share. The result seems to be much more pronounced for the stock market than for the housing market. Stock markets have reached historically high valuations in many advanced economies in recent years as total market capitalization often exceeds one year's GDP. In the end, it is thus not surprising that growth in the stock market ultimately translates into higher capital income as a share of GDP. The effect of home prices, on the other hand, might be more muted for two reasons. First, house prices have stayed fairly constant in real terms in advanced economies for a very prolonged time period and only started to increase rapidly form the 1970s onwards. Second, home ownership is relatively high in many of the countries in our dataset, meaning that house prices might only affect capital income via imputed rents, which might not be measured accurately. More recently, Larry Summers (2014) has argued that advanced economies have entered a new growth regime, the secular stagnation regime, which translates into lower real growth rates as well as a lower natural (or Wicksellian) rate of interest across developed countries. Low interest rates support high asset valuations for two reasons. First, the natural mechanism by which all future income streams are discounted with a lower rate of interest. Second, it might also encourage a certain reach for yield and speculative behavior.

As such, our analysis shows that in the secular stagnation regime one might also have to expect a lower labor share since high market valuations of financial assets, especially stock prices but also houes prices, tilt away income from labor towards capital (as a percentage of GDP). The distributional consequences are potentially large since capital ownership tends to be highly concentrated in society. This should concern policy makers not only for equity reasons, but also for growth performance reasons, as high levels of inequality seem to be associated with lower growth rates. Policy makers can address this worrying trend by implementing some key economic policies that would curb the surge in capital incomes. Piketty (2014) and Piketty and Saez (2012), for example, suggest a higher taxation on capital income as well as an increase in the estate tax/inheritance tax.

14. Conclusion

Jorda et al. (2015) have documented the spectacular increase in private sector leverage, mostly based on mortgages, in a sample of advanced economies in recent decades. This expansion of debt came hand in hand with large price appreciations in the housing market. There is some reason to believe that a portion of the growth achieved since the 1980s was thus simply bought with cheap credit. Insofar as we have reached now a period of deleveraging after the financial crisis of 2008, one might also expect a period of lower growth in the years to come. It is somewhat surprising that credit and asset growth was even more pronounced in the Nordic economies compared to the Anglo-Saxon countries, and especially the United States. The evolution of the housing and mortgage market combined with the recent increase in the capital share suggests that the Scandinavian economies are not insulated from what seem to be global macroeconomic trends. And low global real interest rates will probably support high asset valuations in the years to come, combined with high debt-to-income ratios and high leverage.

Furthermore, in terms of changes in wealth inequality, the Nordics might also not be that special after all. The stark appreciation of real house prices largely favors home owners who tend to be more wealthy, on average. Similarly, the rise in the capital share also favors asset owners. These two trends are thus exacerbating inequality because asset ownership tends to be highly concentrated in society. The Bengtsson-Waldenström database also contains data for top income shares. Table 3 in in appendix contains some basic correlation coefficients between top income shares and the capital share of income. The results suggest that these two measures of inequality are highly correlated, which is not very surprising. In the US, for example, more than 80% of the stock market value is held by the top 10% (Wolff, 2016). Roine and Waldenström (2012) show that the Swedish stock market has performed particularly well since the financial liberalization in the 1980s. Large capital gains have thus contributed to a rise in wealth for the top income shares.

In terms of the capital share, our data reveals that the gross capital share has increased more quickly than the net capital share in recent decades. This suggests that part of the decline in labor income as a share of GDP can simply be attributed to higher economy-wide depreciation. It is still an open debate whether depecriation rates have increased in recent decades because ICT capital becomes obsolete more quickly, whether higher economy-wide depreciation is simply the result of capital deepening, whether this is simply a measurement error, or a combination of all these factors combined. Using various statistical methods, we find strong evidence that stock price appreciations have a causal effect on the functional distribution of income. The result is statistically signifcant across various specifications and also appears to be economically singificant. Our Panel-OLS results suggest that in the short-run an increase in nominal stock prices of 10% is associated with an increase in the capital share of income of about 0.1 to 0.3 percentage points. Our Panel-VAR analysis allows us to estimate the long-run relationship and trace the impulse response functions over time. Our results indicate that an innovation to stock price growth might lead to a cumulative increase to the capital share of about 0.6 to 1.5 percentage points within the subsequent two to three years. On the other hand, no such effect can be found for house prices. However, we did not address the question of imputed rents in our analysis. Home ownership greatly differs across time periods and countries. House price appreications ultimately also tranlsate into higher imputed rents, which would basically lead to an increase in the capital share by definition. Moreover, this effect could be large enough in certain countries so that a higher capital share might simply reflect a statistical anamoly in the national accounts. This would be in line with the findings by La Cava (2016) who shows that imputed rents have increased by about 2 percentage points of GDP since the 1980s. The "secular stagnation" regime suggested by Larry Summers implies rich asset valuations, low real interest rates, and high private sector leverage in the years to come. Our findings are important insofar as our analysis suggests that high asset price growth can also affect the functional distribution of income and further tip the balance away from labor income towards capital income.

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Appendix A

This table contains the estimation results for a simple structural break test. We estimate a linerar trend for the three following macroeconomic variables for each country: the logarithm of real house prices, the mortgage to GDP ratio, and the loans to GDP ratio. We then use the Supremum structural break test (estat sbsingle in Stata). The results indicate that for most countries a structural break occurred in the postwar period, and more specifically post Bretton Woods, which corresponds to the time period of increasing financialization and rising asset prices in advanced economies. We subsequently estimate the linear trend pre-break and post-break. The results indicate that real house prices as well as credit to GDP ratios have grown at a singificantly faster rate for most countries in the sample since the end of Bretton Woods.

Table 1:
Linear time trend model and structural break test

Country	Variable	Starting date	Structural break	Break Year	Structural break test	Entire sample	Pre-break	Post-break
Australia	Ln_real house	1870	YES	1992	0.00***	0.016	0.013	0.046
	Mortg_gdp	1951	YES	1989	0.00***	0.012	0.002	0.028
	Loans_gdp	1947	YES	1986	0.00***	0.018	0.002	0.042
Belgium	Ln_real house	1917	YES	1939	0.00***	0.017	0.033	0.024
	Mortg_gdp	1950	YES	2001	0.00***	0.005	0.003	0.019
	Loans_gdp	1950	YES	1994	0.00***	0.009	0.013	0.006
Canada	Ln_real house	1954	YES	1996	0.00***	0.025	0.027	0.043
	Mortg_gdp	1874	YES	1945	0.00***	0.002	-0.001	0.007
	Loans_gdp	1870	YES	1941	0.00***	0.002	0	0.01
Denmark	Ln_real house	1901	YES	1952	0.00***	0.007	0.002	0.004
	Mortg_gdp	1870	YES	1946	0.00***	0.005	0.009	0.014
	Loans_gdp	1870	YES	1941	0.00***	0.004	0.016	0.01
Finland	Ln_real house	1961	YES	1971	0.00***	0	0.074	-0.006
	Mortg_gdp	1949	YES	1999	0.00***	0.007	0.005	-0.002
	Loans_gdp	1949	YES	1999	0.00***	0.013	0.015	-0.013
France	Ln_real house	1875	YES	1961	0.00***	0.011	0.002	0.013
	Mortg_gdp	1875	YES	1944	0.00***	0.003	0.006	0.013
	Loans_gdp	1875	YES	1941	0.00***	0.005	0.016	0.015

Germany	Ln_real house	1971	YES	2004	0.00***	0.034	0.03	-0.049
	Mortg_gdp	1946	YES	1993	0.00***	0.012	0	0.043
	Loans_gdp	1946	YES	2003	0.00***	0.016	0.009	0.047
Italy	Ln_real house	1905	YES	1925	0.00***	0.018	-0.095	0.018
	Mortg_gdp	1927	YES	1944	0.00***	0.001	-0.008	0.003
	Loans_gdp	1870	YES	1941	0.00***	0.004	0.007	0.008
Japan	Ln_real house	1870	YES	1960	0.00***	0.01	-0.013	0.024
	Mortg_gdp	1950	YES	1998	0.00***	0.006	0.005	0.021
	Loans_gdp	1950	YES	1995	0.00***	0.009	0.01	0.02
Netherlands	Ln_real house	1945	YES	1958	0.00***	0.028	-0.025	0.032
	Mortg_gdp	1880	YES	1982	0.00***	0.004	0.002	0.014
	Loans_gdp	1880	YES	1967	0.00***	0.006	0	0.02
Norway	Ln_real house	1970	YES	1983	0.00***	0.015	0.057	0.015
	Mortg_gdp	1870	YES	1992	0.00***	0.002	0.001	0.021
	Loans_gdp	1870	YES	1992	0.00***	0.005	0.004	0.023
Portugal	Ln_real house	1936	YES	1958	0.00***	0.048	-0.012	0.017
	Mortg_gdp	1946	YES	1967	0.00***	0.007	0.001	0.008
	Loans_gdp	1946	YES	2000	0.00***	0.01	0.01	-0.002
Spain	Ln_real house	1870	YES	1936	0.00***	0.006	0	0.023
	Mortg_gdp	1945	YES	1998	0.00***	0.01	0.006	0.009
	Loans_gdp	1945	YES	1975	0.00***	0.02	0.008	0.03
Sweden	Ln_real house	1871	YES	1976	0.00***	0.003	-0.004	0.037
	Mortg_gdp	1946	YES	1986	0.00***	0.009	0.003	0.02
	Loans_gdp	1946	YES	1970	0.00***	0.011	0.011	0.015
Switzerland	Ln_real house	1988	YES	2000	0.00***	-0.008	-0.001	-0.03
	Mortg_gdp	1920	YES	1995	0.00***	0.005	0.002	0.025
	Loans_gdp	1920	YES	1987	0.00***	0.013	-0.006	0.043
UK	Ln_real house	1875	YES	1993	0.00***	0.004	0.001	0.061
	Mortg_gdp	1871	YES	1946	0.00***	0.003	0.001	0.007
	Loans_gdp	1871	YES	1936	0.00***	0.003	0.004	0.009
USA	Ln_real house	1890	YES	1946	0.00***	0.008	0.007	0.004
	Mortg_gdp	1880	YES	1936	0.00***	0.002	0.002	0.004
	Loans_gdp	1880	YES	1935	0.00***	0.002	0.005	0.005

Source: Author's calculation

Appendix B

The appendix contains the regression results from our Panel-OLS regressions for the various specifications.

Table 1:
Panel-OLS model, Specification I

	(1)	(2)	(3)	(4)	(5)
	1875 - 2013	**1875 - 1944**	**1945 - 2013**	**1945 - 1973**	**1974 - 2013**
Observations	1491	493	998	364	634
Δ y	10.06**	17.09***	18.28***	13.96*	43.43***
	(3.89)	(4.38)	(6.12)	(7.7)	(5.62)
y gap	-10.19*	-12.09*	-3.3**	-9.95	-17.49**
	(5.7)	(6.17)	(9.08)	(10.91)	(8.24)
stir	-0.009	0.098	0.01	-0.74***	-0.016
	(0.06)	(0.2)	(0.06)	(0.19)	(0.04)
Δ cpi	-4.85**	-4.3*	-5.77	8.35*	4.7
	(2.28)	(2.38)	(3.95)	(4.62)	(4.62)
Δ m	-1.98	5.06	-3.29	5.39	-0.36
	(2.09)	(3.31)	(2.27)	(4.66)	(1.38)
Δ c	0.24	-0.84	-4.43**	-1.72	-2.91*
	(1.66)	(2.04)	(2.25)	(3.53)	(1.65)
Trade openness	12.95***	7.22**	5.87***	0.81	9.81***
	(1.62)	(3.48)	(2.15)	(4.63)	(1.43)
Government. expenditure	-12.93***	-12.53***	-16.71***	-22.74***	-8.12***
	(2.05)	(2.75)	(3.43)	(6.77)	(3.11)
Within R2	0.65	0.54	0.57	0.74	0.8

Source: Author's calculations

Table 2:
Panel-OLS model, Specification II

	(1)	(2)	(3)	(4)	(5)
	1875 - 2013	**1875 - 1944**	**1945 - 2013**	**1945 - 1973**	**1974 - 2013**
Observations	1262	362	900	283	617
Δ y	5.94	4.65	29.9***	14.35**	31.91**
	(3.87)	(4.78)	(5.4)	(6.41)	(6.37)
y gap	-0.33	4.19	-11.58	-3.41	-17.44*
	(5.87)	(6.83)	(8.13)	(9.46)	(8.97)
stir	0.085	0.78***	-0.028	-0.57***	0.013
	(0.06)	(0.22)	(0.05)	(0.16)	(0.04)
Δ cpi	-4.83**	-6.55**	9.22***	19.23***	-10.05*
	(2.2)	(2.58)	(3.49)	(3.61)	(5.24)
Δ m	-1.21	4.4	-1.99	6.06	-0.41
	(2.02)	(3.77)	(1.8)	(3.68)	(1.38)
Δ c	1.09	-3.47	-3.18	-2.69	-2.03
	(1.75)	(2.44)	(1.98)	(2.84)	(1.79)
Trade openness	14.61***	4.28	7.04***	9.38**	8.5**
	(1.63)	(3.72)	(1.75)	(3.62)	(1.5)
Government. expenditure	-15.66***	-19.79***	-20.8***	-24.18***	-8.99***
	(2.05)	(3)	(2.89)	(5.72)	(3.15)
$\Delta\ stock$	2.68***	3.94***	1.59***	0.79	1.25***
	(0.62)	(1.29)	(0.53)	(0.91)	(0.42)
L1 ($\Delta\ stock$)	2.01***	2.47**	0.99*	0.67	0.64
	(0.6)	(1.21)	(0.52)	(0.97)	(0.4)
L2 ($\Delta\ stock$)	2.14***	1.83	1.29**	0.47	0.9**
	(0.61)	(1.19)	(0.52)	(0.98)	(0.4)
$\Delta\ house$	-0.17	1.3	0.99	2.6*	1.49
	(1.15)	(1.78)	(1.11)	(1.35)	(1.21)
L1 ($\Delta\ house$)	-0.32	1.24	-0.15	1.42	1.08
	(1.15)	(1.71)	(1.15)	(1.33)	(1.23)
L2 ($\Delta\ house$)	-1.83*	1.07	-2*	-0.36	-2.05*
	(1.1)	(1.67)	(1.08)	(1.29)	(1.13)
Within R2	0.67	0.64	0.7	0.81	0.82

Source: Author's calculations

Table 3:
Panel-OLS model, Specification III

	(1)	(2)	(3)	(4)	(5)
	1875 - 2013	**1875 - 1944**	**1945 - 2013**	**1945 - 1973**	**1974 - 2013**
Observations	1262	362	900	283	617
Δ y	6.44*	4.8	31.12***	15.08**	34.22***
	(3.83)	(4.7)	(5.31)	(6.24)	(6.11)
y gap	-0.4	4	-12.21	-3.8	-17.24*
	(5.83)	(6.77)	(7.99)	(9.26)	(8.79)
stir	0.079	0.79***	-0.036	-0.55***	-0.001
	(0.06)	(0.22)	(0.05)	(0.15)	(0.04)
Δ cpi	-4.55**	-6.24**	9.57***	19.62***	-8.75*
	(2.19)	(2.55)	(3.47)	(3.57)	(5.21)
Δ m	-1.03	4.61	-1.64	7.24**	-0.18
	(2.01)	(3.75)	(1.79)	(3.55)	(1.38)
Δ c	1.01	-3.73*	-2.94	-2.3	-1.81
	(1.75)	(2.4)	(1.97)	(2.8)	(1.79)
Trade	14.65***	4.58***	7.35***	9.92***	8.83***
openness	(1.64)	(3.7)	(1.74)	(3.59)	(1.49)
Government.	-15.57***	-19.44***	-21.04***	-25.56***	-8.83***
expenditure	(2.05)	(3.7)	(2.87)	(5.6)	(3.15)
Δ *stock*	6.96***	8.2***	3.11***	2.2	3.05***
mov. avg.	(1.11)	(2.44)	(0.95)	(1.75)	(0.75)
Δ *house*	-2.49	3.11	-1.36	-3.35	0.42
mov. avg.	(1.69)	(2.63)	(1.79)	(2.53)	(1.66)
Within R2	0.67	0.63	0.7	0.81	0.82

Source: Author's calculations

Table 4:
Panel-OLS model, Specification IV

	(1)	(2)	(3)	(4)	(5)
	1875 - 2013	**1875 - 1944**	**1945 - 2013**	**1945 - 1973**	**1974 - 2013**
Observations	1262	362	900	283	617
Δ y	7.59*	5.39	32.17***	12.39*	36.07***
	(3.92)	(4.88)	(5.4)	(6.32)	(6.34)
y gap	-1.3	4.91	-12.12	0.38	-20.13**
	(5.94)	(6.94)	(8.11)	(9.27)	(8.95)
stir	0.04	0.7***	-0.05	-0.61***	-0.001
	(0.06)	(0.22)	(0.05)	(0.15)	(0.04)
Δ cpi	-4.01*	-6.15**	9.08***	20.34***	-7.71
	(2.23)	(2.61)	(3.45)	(3.55)	(5.22)
Δ m	-0.32	8.75**	-2.02	6.91*	-0.37
	(2.03)	(3.67)	(1.81)	(3.67)	(1.39)
Δ c	1.9	-2.26	-2.91	-1.8	-1.33
	(1.72)	(2.47)	(1.86)	(2.81)	(1.72)
Trade openness	15.07***	5.87	7.48***	10.22***	8.54***
	(1.66)	(3.78)	(1.76)	(3.6)	(1.49)
Government. expenditure	-15.6***	-20.58***	-19.63***	-25.73***	-7.88**
	(2.08)	(3.04)	(2.88)	(5.68)	(3.07)
D1(Δ stock)	0.29	0.82	0.23	0.03	0.22
	(0.48)	(0.96)	(0.41)	(0.69)	(0.32)
L(D1(Δ stock))	0.21	0.7	0.04	0.15	0.004
	(0.48)	(0.91)	(0.41)	(0.74)	(0.32)
D1(Δ house)	1.33	0.41	1.9**	1.39	1.75*
	(0.98)	(1.56)	(0.9)	(1.01)	(0.99)
L(D1((Δ house))	1.82*	0.87	2.05**	1.61	2.75***
	(0.96)	(1.46)	(0.91)	(1)	(0.95)
Within R2	0.66	0.62	0.69	0.81	0.81

Source: Author's calculations

Table 5:
Panel-OLS model, Specification V

	(1)	(2)	(3)	(4)	(5)
	1875 - 2013	**1875 - 1944**	**1945 - 2013**	**1945 - 1973**	**1974 - 2013**
Observations	1289	377	912	293	619
Δ y	6.8*	6.61	32.11***	15.28**	34.91***
	(43.83)	(4.63)	(5.35)	(6.06)	(6.36)
y gap	-0.37	3.22	-12.88	-1.57	-15.39*
	(5.78)	(6.58)	(8.12)	(9.05)	(9.3)
stir	0.058	0.68***	-0.039	-0.56***	0.004
	(0.06)	(0.21)	(0.05)	(0.15)	(0.04)
Δ cpi	-3.45	-6.29**	8.58**	19.05***	-5.28
	(2.16)	(2.47)	(3.4)	(3.53)	(5.16)
Δ m	-0.6	9.79***	-2.48	7.04*	-0.83
	(2)	(3.56)	(1.81)	(3.61)	(1.4)
Δ c	1.74	-1.94	-2.97	-1.92	-1.78
	(1.63)	(2.25)	(1.83)	(2.73)	(1.69)
Trade openness	15.16***	6.83*	7.48***	10.8***	8.49***
	(1.62)	(3.66)	(1.74)	(3.78)	(1.5)
Government. expenditure	-15.5***	-20.49***	-19.11***	-24.16***	-8.97***
	(2.04)	(2.96)	(2.81)	(5.41)	(3.08)
HP gap stock	1.65*	-0.04	1.66**	0.78	1.23**
	(0.9)	(2.53)	(0.76)	(1.21)	(0.61)
L1(HP gap stock)	-0.29	-1.61	-0.31	-0.71	-0.05
	(0.87)	(1.69)	(0.74)	(1.24)	(0.59)
HP gap house	-1.13	1.12	1.31	5.05**	-1.56
	(1.79)	(2.52)	(1.8)	(2.06)	(1.91)
L1(HP gap house)	-2.76	-1.86	-2.93*	-0.53	-3.01
	(1.76)	(2.6)	(1.7)	(1.97)	(1.81)
Within R2	0.67	0.63	0.7	0.81	0.81

Source: Author's calculations

Table 6:
Panel-OLS model, Specification VI

	(1)	(2)	(3)	(4)	(5)
	1875 - 2013	**1875 - 1944**	**1945 - 2013**	**1945 - 1973**	**1974 - 2013**
Observations	1276	370	906	288	618
Δ y	6.33*	5.8	30.85***	13.52**	34.26***
	(3.79)	(4.47)	(5.35)	(6.18)	(6.29)
y gap	-0.93	2.39	-11.08	-2.37	-17.44*
	(5.77)	(6.5)	(8.06)	(9.14)	(8.97)
stir	0.06	0.73***	-0.035	-0.57***	-0.001
	(0.06)	(0.21)	(0.05)	(0.15)	(0.04)
Δ cpi	-4.26*	-6.59***	8.18**	19.39***	-8.83*
	(2.17)	(2.43)	(3.42)	(3.49)	(5.22)
Δ m	-1.3	5.48*	-2.27	6.01	-0.48
	(2.01)	(3.54)	(1.81)	(3.64)	(1.39)
Δ c	0.61	-2.92	-3.47*	-2.11	-2.42
	(1.66)	(2.2)	(1.93)	(2.79)	(1.76)
Trade openness	14.91***	4.64	7.36***	9.5***	9.07***
	(1.63)	(3.59)	(1.74)	(3.57)	(1.49)
Government. expenditure	-15.79***	-20.71***	-20.11***	-24.36***	-7.89**
	(2.03)	(2.88)	(2.85)	(5.53)	(3.09)
Std. dev. $\Delta\, stock$	0.5***	0.76**	0.29***	0.19	0.25***
	(0.11)	(0.22)	(0.1)	(0.16)	(0.08)
L1(Std. dev. $\Delta\, stock$)	0.38***	0.44**	0.2**	0.16	0.14*
	(0.11)	(0.22)	(0.1)	(0.18)	(0.07)
Std. dev. $\Delta\, house$	0.12	0.43**	0.09	0.2	0.18
	(0.12)	(0.2)	(0.11)	(0.14)	(0.11)
L1(Std. dev. $\Delta\, house$)	0.06	0.21	0.01	0.12	0.06
	(0.12)	(0.19)	(0.11)	(0.14)	(0.11)
Within R2	0.67	0.66	0.7	0.81	0.82

Source: Author's calculations

Table 7:
Panel-OLS model: OECD data

	(1)	(2)	(3)	(4)	(5)	(6)
	1970 -2013	1970 -2013	1970 -2013	1970 -2013	1970 -2013	1970 -2013
Observations	700	688	690	688	690	690
$\Delta\, y$	47.4*** (4.9)	35.52*** (5.29)	38.57*** (5.13)	41.83*** (5.39)	41.03*** (5.39)	37.49*** (5.21)
y gap	-17.48** (7.2)	-10.53 (7.59)	-12.79* (7.58)	-13.06* (7.78)	-10.75 (8.07)	-9.58 (7.61)
stir	0.04 (0.04)	0.053 (0.04)	0.041 (0.04)	0.039 (0.04)	0.049 (0.04)	0.054 (0.04)
$\Delta\, cpi$	6.06 (4.12)	-3.37 (4.46)	0.22 (4.37)	1.78 (4.54)	5.06 (4.38)	-1.32 (4.4)
$\Delta\, m$	2.47 (1.23)	2.39 (1.19)	2.35* (1.21)	2.6** (1.24)	1.95 (1.24)	2.19* (1.2)
$\Delta\, c$	1.92 (1.43)	0.55 (1.52)	0.66 (1.52)	2.56* (1.5)	2.55* (1.49)	0.95 (1.5)
Open	4.7*** (1.2)	4.62*** (1.2)	4.69*** (1.2)	4.49*** (1.22)	4.93*** (1.26)	4.5*** (1.17)
Gov. exp.	-6.98*** (2.51)	-8.31*** (2.61)	-6.81*** (2.56)	-7.26*** (2.63)	-7.23*** (2.57)	-7.12*** (2.54)
Unionization	-0.04* (0.02)	-0.05** (0.02)	-0.05** (0.02)	-0.04** (0.02)	-0.03* (0.02)	-0.05** (0.02)
Unemployment	0.36*** (0.04)	0.36*** (0.04)	0.37*** (0.04)	0.36*** (0.04)	0.36*** (0.04)	0.36*** (0.04)
$\Delta\, stock$	-	1.65*** (0.36)	-	-	-	-
L1($\Delta\, stock$)	-	1.42*** (0.35)	-	-	-	-
L2($\Delta\, stock$)	-	1.15*** (0.34)	-	-	-	-
$\Delta\, house$	-	0.95 (1.03)	-	-	-	-
L1($\Delta\, house$)	-	1.79* (1.05)	-	-	-	-
L2($\Delta\, house$)	-	0.34 (0.97)	-	-	-	-
$\Delta\, stock$ *mov. avg.*	-	-	2.41*** (0.49)	-	-	-
$\Delta\, house$ *mov. avg.*	-	-	3.37*** (1.16)	-	-	-
D1($\Delta\, stock$))	-	-	-	0.14 (0.28)	-	-
L(D1($\Delta\, stock$))	-	-	-	0.19 (0.27)	-	-
D1($\Delta\, house$)	-	-	-	0.38 (0.87)	-	-
L(D1(($\Delta\, house$))	-	-	-	1.62* (0.84)	-	-
HP gap stock	-	-	-	-	1.38*** (0.52)	-

L1(HP gap stock)	-	-	-	-	0.44 (0.51)	-
HP gap house	-	-	-	-	-2.28 (2.26)	-
L1(HP gap house)	-	-	-	-	-0.3 (1.58)	-
Std. dev. $\Delta stock$	-	-	-	-	-	0.32*** (0.07)
L1(Std. dev. $\Delta stock$)	-	-	-	-		0.29*** (0.07)
Std. dev. $\Delta house$	-	-	-	-	-	0.09 (0.1)
L1(Std. dev. $\Delta house$)	-	-	-	-	-	0.19 (0.1)
Within R^2	0.72	0.74	0.74	0.72	0.73	0.74

Source: Author's calculations

Appendix C

The appendix contains a few additional results concerning correlations between pribvate debt and asset prices as well different measures of inquality.

Table 1:
Correlation between total private sector loans and mortgages:

Correlation coefficient	$\boldsymbol{mortgage/GDP}$	$\boldsymbol{\Delta\ mortgage/GDP}$
$\boldsymbol{loan/GDP}$	0.906	
$\boldsymbol{\Delta\ loan/GDP}$		0.7

Source: Jorda, Schularick and Taylor (2016a) Macrohistory database. Author's calculations

The table displays the correlation between private sector loans and mortgages and also the correlation in first differences. Both correlation coefficients are extremely high, as was to be expected, given that mortgages are nowadays a substantial fraction of total private sector credit across advanced economies.

Table 2:
Correlation between house price changes and credit growth

	$\boldsymbol{\Delta real\ house\ price}$
$\boldsymbol{\Delta\ loan/GDP}$	0.17
LAG 1 ($\boldsymbol{\Delta\ loan/GDP}$)	0.124
LAG 2 ($\boldsymbol{\Delta\ loan/GDP}$)	0.039
$\boldsymbol{\Delta\ mortgage/GDP}$	0.154
LAG 1 ($\boldsymbol{\Delta\ mortgage/GDP}$)	0.098
LAG 2($\boldsymbol{\Delta\ mortgage/GDP}$)	0.009
$\boldsymbol{\Delta\ real\ stock\ price}$	0.163

Source: Jorda, Schularick and Taylor (2016a) Macrohistory database. Author's calculations

The table displays correlation coefficients for house price growth and private sector credit growth, including their lags.

Table 3:
Correlations capital share and top income shares

	gross capital share	net capital share	OECD capital share	top 0.1%	top 1%	top 10%
gross capital share	1.00					
net capital share	0.91	1.00				
OECD capital share	0.46	0.34	1.00			
top 0.1%	0.43	0.54	0.08	1.00		
top 1%	0.11	0.16	0.28	0.44	1.00	
top 10%	0.36	0.51	-0.12	0.62	-0.27	1.00

Bengtsson and Waldenström (2015) capital share database. Author's calculations

The table displays correlation coefficients for the top income shares as well as for three measures of the capital share. We find a singificant positive correlation between top-income shares and the functional distribution of income, as was to be expected, since capital income is highly concentrated in society.

Paper III

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Global real interest rate dynamics from the late 19th century to today

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A R T I C L E I N F O

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A B S T R A C T

There is a long-standing economic debate to what extent interest rates are determined by domestic versus international forces. Using a time series factor model, we estimate two common global factors for the short-term real interest rate for a panel of 17 advanced economies from 1871 to 2013. Our analysis shows that more than 50% of the variation in national real interest rates can be explained by our two international factors alone. While our data encompasses several macroeconomic regime changes, we find in general that real interest rates are more responsive to international conditions during times of high international capital mobility, such as the post Bretton Woods period. Our first common global factor can be interpreted as an approximation of the global short-term equilibrium real interest rate. Using an error-correction approach, we show that that the global real interest rate acts as a force of attraction for national real interest rates. Moreover, our factor analysis can also explain the long-term downward trend of national real interest rates that started in the 1980s, meaning that the forces of secular stagnation have acted on a global level. Finally, we estimate a Panel-VAR model, which allows us to show that the national business cycle is highly responsive to our two common global factor variables, thus indicating that small economies have increasing difficulties to insulate themselves from international macroeconomic conditions. Our analysis is important insofar as it shows that during periods of high capital mobility Central Banks might have even less influence in setting the domestic short-term real interest rate than what is commonly assumed by most neo-keynesian macroeconomic models.

1. Introduction

It is well known that real interest rates around the world have been declining over the last few decades and some authors even suggest that interest rates nowadays are at their lowest point ever recorded in history (Schmelzing, 2017). While many economists have recently pointed towards domestic factors that can explain the long-term decline in equilibrium real interest rates in the US, such as Summers (2014) for example, there surely seem to be global forces at work as well (Rachel & Smith, 2015). In this paper we will address the following questions: To what extent are domestic short-term real interest rates dependent on global macroeconomic forces and how has this relationship changed over time and across monetary regimes? Does the ongoing process of globalization with increased capital mobility imply that real interest rates are more or less decoupled from domestic macroeconomic variables? Are those global forces good predictors of future movements in real interest rates and to what extent can they explain the global and secular downward trend over the last couple of decades? All these questions seem to be important, both from a theoretical as well as from a practical point of view, as policy makers and especially Central Bankers have grappled with years of low nominal interest rates in the aftermath of the Global Financial Crisis.

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Most advanced economies have seen over the last decade a remarkable productivity slump combined with a prolonged period of both low nominal as well as real interest rates in the aftermath of the financial crisis of 2008. Larry Summers (2014) has recently revived the theory of secular stagnation, arguing that we have entered a new macroeconomic regime in which many countries will repeatedly suffer from negative aggregate demand shocks in the face of such low interest rates, which will give little leeway for Central Banks to counter adverse macroeconomic shocks. The secular stagnation theory argues that a number of factors have led to a decline in the equilibrium real interest rate. These forces include rapidly ageing societies, an increase in inequality, a decline in the demand for productive investment (Summers, 2014), and finally a potential slowdown in productivity as argued by Gordon (2017). More recently, Eggertson et al. (2016) have formally shown that secular stagnation can be transmitted from country to country via international capital flows.

However, from a theoretical perspective, we still miss a satisfactory theory of interest determination in the open economy setting. Most standard macroeconomic models explain the determination of interest rates within the closed economy. More recently, the literature on micro-founded open economy models has advanced substantially, incorporating specific open economy factors like home bias in consumption (Coeurdacier & Rey, 2013). Nevertheless, many of those models are far from ready to analyze some important issues, such as interest rate equalization in global capital markets with various degrees of capital mobility between countries (Brzoza-Brzezina and Cuaresma, 2007).

From a policy point of view, the question whether short-term interest rates are determined more by domestic factors or international factors is also of crucial importance. Especially for small and open economies with floating exchange rates this begs the question on how independent monetary policy really is. Some research, such as Rey (2015), suggests that within the context of international capital mobility and international credit cycles most Central Banks actually have very little monetary autonomy to begin with. Consider the case of Sweden where the Swedish Riskbank autonomously sets its own policy interest rate. However, in reality the Swedish rate seems to follow extremely closely the policy rate set by the ECB in Frankfurt, thus casting some doubt to what extent Swedish monetary policy is really independent from outside forces, or whether the Riksbank is basically forced to shadow the behavior of the ECB. Fig. 1 displays the 3-month interbank lending rate for the Eurozone and Sweden, respectively. The correlation coefficient between the two time series exceeds 93%. As suggested by Andersson and Jonung (2015), the Riksbank has lost control over the domestic interest rate as a result of capital flows from and to the rest of the world.

In this paper, we study to what extent global factors affect domestic short-term real interest rates. We take a very long view and analyze data from the Jorda, Schularick, and Taylor (2017) Macrohistory database for 17 advanced economies from the 1870s until today, thus encompassing several international macroeconomic regime switches. The global monetary system underwent several fundamental changes since the late 19th century. Most countries had adopted the classical gold standard by about 1870 when our data set begins. With the beginning of World War I, some countries like the UK opted out of the gold standard, mostly because it would allow them to finance their war efforts with expansionary monetary policy. During the interwar period, the gold standard was reintroduced, which ultimately culminated in the Great Depression. The post-World War II period was characterized by a regime of fixed exchange rates and limited capital mobility, also known as the Bretton Woods arrangement. This regime broke down in the early 1970s when the US was unwilling to defend the dollar peg.

While factor analysis has become a more prominent toolkit in macroeconomic research in general in recent years, macroeconomists mostly employ dynamic factor analysis, which relies commonly on Bayes estimation and imposes many priors on the structure of the parameters beforehand (Lopes & West, 2004). In the dynamic stochastic general equilibrium (DSGE) literature, those priors generally serve to overcome the lack of identification of some of the parameters in the model (Stock and Watson, 2011). However, imposing a number of restrictions beforehand rather seems to be a weakness of the method. While many papers have employed dynamic factor analysis to address questions related to the estimation of global business cycle variables (Forni, Hallin, Marco Lippi, & Reichlin, 2000), or the dynamics of international real interest rates and term structures (Abritti et al., 2013), most research is limited to the post Bretton Woods period, such as Del Negro et al. (2008).

The contibution of this paper is to employ a different methodology, the time series factor analysis (henceforth TSFA) suggested by Gilbert and Meijer (2005), which seems to be more suited for explanatory factor analysis in general, and to study the behavior of real interest rates across several macroeconomic regimes over the course of more than a century for 17 advanced economies. We therefore hope to gain additional insights on global real interest rate dynamics across different time periods in order to assess the relevance of Central Banks in determining domestic macroeconomic conditions. Surely, the international context and the global monetary regime in place matter a great deal for Central Banks' relative ability to influence the domestic rate of interest.

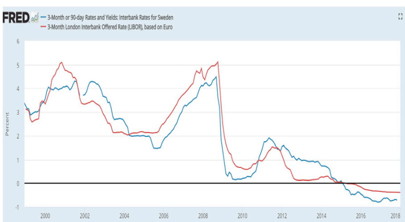

Fig. 1. 3-month interbank rate for Sweden and the Eurozone.
Source: FRED.

As was to be expected, our analysis reveals that the extent to which global forces affect the domestic short-term real interest rate is highly dependent on the global macroeconomic regime in place, and more specifically, the extent of global capital mobility. We perform a TSFA, which shows that a large fraction of the variation in domestic real interest rates can be explained by two common global factors alone. To the best of our knowledge, this is the first time this method is employed to a macroeconomic panel data set that spans across more than 140 years of data and thus encompasses several global macroeconomic regime changes. Our findings indicate that about 60% of the domestic real interest rate variation over the entire time period can be explained by our factor analysis. Unsurprisingly, this number is lower for the period of fixed exchange rates during Bretton Woods, but increases to more than 70% for the period of floating exchange rates and high capital mobility after 1973. Moreover, using an error correction model (ECM), we show that the first common global factor acts as an attractor for national real interest rates. This finding is consistent with the small-country assumption, which implies that most economies have little to no impact on international macroeconomic conditions and international factor prices, with the US being the notable exception. We also show that our first common factor can be interpreted as the global equlibrium short-term real interest rate and that it can explain a large part of the secular downward trend for national real interest rates since the 1980s. This seems to imply that some of the forces of secular stagnation are determined by global macroeconomic factors instead of domestic macroeconomic conditions. Time series factor analysis can thus be used as a viable alternative method for macroeconomists to estimate the global equilibrium real interest rate. Last but not least, we use a Panel-VAR approach and show that our two common global factors have a significant impact on the national business cycle. Especially during the period of floating exchange rates, the two common global factors have a sizeable effect not only on national GDP growth rates but also on monetary variables and asset prices. This seems to suggest that is has become more and more diffcult for national economies to insulate themselves from international macroeconomic conditions, which is exactly what one would expect during times of high capital mobility and increasing global interdependency between national financial markets and asset prices (Jordà, Schularick, Taylor, & Ward, 2018).

2. Theory and related literature

Knut Wicksell's (1907) original work "Geldzins and Güterpreise" ("Interest and Prices") is one of the first and certainly also most influential theoretical contributions on the determination of interest rates. Most neo-keynesian macroeconomic models have incorporated the Wicksellian approach on how interest rates are formed and determine macroeconomic outcomes. It should be noted though that there exist several different theories in the classical economics literature on how interest rates are determined, depending on the underlying macroeconomic model in question. Baker, De Long, and Krugman (2005), for example, derive the real interest rate in more standard neoclassical growth models like the Solow-Swan and the Cass-Koopmans-Ramsey model. The authors show that in the long-run the real interest rate is determined solely by structural factors, which are the rate of labor productivity and population growth. Moreover, these models make a relatively clear prediction about the interest rate elasticity with respect to those two parameters. The standard result is that a decline in labor productivity leads to a more than one-to-one long-run decline in the real rate of interest (Baker et al., 2005). Falling population growth should also lead to a lower real interest rate, with an interest rate elasticity exceeding one in the Solow model while the elasticity is smaller than one in the Cass-Ramsey-Koopmans model.

Standard neoclassical growth models thus point towards the stylized fact that advanced economies have entered a regime of declining real interest rates combined with slow population growth and low changes in labor productivty. More recently, Lu and Teulings (2016) have shown that within an overlapping-generations model with different cohort sizes, i.e. shrinking population, one can generate a negative real interest rate in steady state. This is the so-called "secular stagnation regime". Note, however, that all these results are steady state outcomes that are only achieved in the long-run equilibirum. From an empirical point of view, it is relatively hard to establish causality between these structural parameters and the real rate of interest. Bosworth (2014), for example, notes that in reality domestic factors, such as the labor force growth or even GDP growth, have little to no explanatory power in explaining real interest rates in a sample of G20 economies.

In the short to medium run, the real interest rate is determined by a range macroeconomic factors that affect the business cycle. Most neo-keynesian models assume that Central Banks have some control over short-term real interest rates over a time horizon of up to several years, and also over long-term real interest rates via the expectations hypothesis. More specifically, Central Banks are assumed to follow something like the Taylor rule where they respond to deviations from the inflation target as well as to deviations from the natural rate of output:

$$r_t = r^* + h(\pi_t - \pi^*) + b(y_t - y^*) + \varepsilon_t \tag{1}$$

h and b are coefficients that according to the classical Taylor rule assume a value of 0.5, ε_t is an error term that reflects idiosyncratic risk factors, and r^* is the natural rate of interest, which is determined by long-run structural paremeters, i.e. the supply-side of the economy as well as fiscal variables (Sørensen & Whitta-Jacobsen, 2005). While most macroeconomic models thus assert that Central Banks have a reasonable degree of control over short-term interest rates, the empirical literature has found that world factors have become an important determinant in setting domestic interest rates. More recently, some DSGE models have incorporated those open-ecomomy dynamics (Brzoza-Brzezina and Cuaresma, 2007). However, from a theoretical point of view, we still lack a very good microfounded theory on how interest rates are determined in the open-ecomomy setting, thus leaving an important role to empirical papers in establishing to what extent international factors can account for real interest rate fluctuations. In this spirit, Ford and Laxton (1995) conclude that the world public debt-to-GDP ratio boosts real interest rates while own-country debt variables are mostly insignificant. Christiansen and Piggot (1997) show that long-term interest rates in 10 OECD countries are affected by foreign interest rates, a result that has also been confirmed by Bosworth (2014). Important spillover effects between the US interest rate and the Eurozone interest rate have been documented by Chinn and Frankel (2003). Similarly, Beckworth and Crowe (2012) demonstrate that the interest rate set by the ECB tends to follow the rate set by the Federal Reserve by a couple of years, thus confirming the Fed's predominant role in determining global monetary conditions. Brzoza-Brzezina and Cuaresma (2007) use a dynamic factor model and show that international factors can account for a large fraction of domestic real interest rate movements. Some papers, like Ratti and Vespignani (2015), use principal component analysis to estimate a global real interest rate and then study the behavior of the global economy in a structural VAR model. Their findings indicate that global real interest rates are positively correlated with the global business cycle. Summing up, many empirical papers have found that global factors are of crucial importance in determining national real interest rate. This paper adds to the research by analysing short-term real interest rates over a time span of more than 140 years and across several global monetary regimes for our sample of 17 countries. We therefore gain additional insights on the dynamics of real interest rates over the last century, including the time period of Bretton Woods when capital mobility was extremely limited compared to today.

3. Data

For the purpose of our study, we rely on the Macrohistory database by Jorda, Schularick, and Taylor (2017), which gives us a unique macroeconomic panel dataset comprising 17 advanced economies with annual time series data going back to 1870. The data set includes our key variables of interest, which are the short-term and long-term nominal interest rate, the rate of consumer price inflation (CPI), and real GDP growth. The short-term nominal interest rate is measured as the interest rate on savings deposits, money market funds, or short-term government securities, depending on the country and the time period in question, whereas the long-term interest rate usually corresponds to the interest rate on consols and long-term government bonds with a maturity of ten years.[1] While the Federal Reserve, for example, does not target the interest rate on savings deposits or money market funds, these financial instruments are usually very tightly linked to the federal funds rate, which is directly controlled by the Fed, meaning that we can treat them in practice as equivalent. A similar reasoning, of course, applies to the other countries in our data set. We obtain a measure for the real interest rate for each country by using the relevant short-term nominal interest rate and subtracting the rate of inflation, which is defined as the logarithmic difference of the CPI:

$$r_{short-term,t} = i_{short-term,\ t} - (\ln CPI_t - \ln CPI_{t-1}) = i_{short-term,\ t} - \pi_t \tag{2}$$

Our data thus comprises 143 years of data for the ex-post real interest rate from 1871 to 2013 for the 17 countries in our panel (see Table 1). As there are some missing observations for a few countries, we have to make a few adjustments in order to complete the data set. We simply use the long-term interest rate i_{bonds} instead if it is available for that particular year. For some of the observations where neither the short-term nor the long-term nominal interest rate is existent, we have to make an assumption about the nominal interest rate and then simply subtract the rate of inflation (consult the appendix for specifics).

4. Historical context

Since we examine the behavior of the short-term real interest rates over a time span than of more than 140 years, the historical context is extremely important. More specifically, the global monetary system underwent several important regime changes from the end of the 19th century to today. By the late 1870s when our data starts, 14 out of the 17 countries in our sample had joined the classical gold standard,[2] meaning that the currencies were pegged to the price of gold and thus also fixed with respect to each other. Unfortunately, there is a great deal of confusion on how the gold standard worked in practice, a mistake commonly attributed to David Hume who suggested the price-specie flow mechanism (Laidler, 1981). More recently, McCloskey and Richard Zecher (2013), on the other hand, have shown that the aforementioned mechanism did not really apply. During the classical gold standard, the global price level is determined internationally by the global demand and supply for gold and domestic price levels have to adjust accordingly based on international goods arbitrage. Moreover, Central Banks also have very limited control over domestic interest rates, which are determined by financial arbitrage in international capital markets and are thus endogenous to macroeconomic conditions. While Central Banks promise to maintain convertibility of domestic currency to gold at a fixed exchange rate, this promise does not in fact constrain Central Banks from adjusting their domestic policy rate or even the domestic money supply in accordance with their own policy goals. It is true that domestic credit is to some extent restricted by the amount of gold reserves, but this has to do more with the reserve ratio set by the Central Bank, which could in theory be adjusted at any time. Under the classical gold standard, Central Banks thus exert little influence on the domestic price level, which is determined by the global market for gold. Consequently, the period of the classical gold standard was characterized by prolonged periods of deflation during times when the supply of gold could not keep up with demand. In fact, global goods prices were falling for almost two decades from about 1870 to 1890 and the correlation of cross-country inflation rates was quite high (see Fig. 6 below). Moreover, the period also experienced a high degree of capital mobility (Eichengreen, 1998). The time of the classical gold standard was a macroeconomic regime characterized by relatively deep economic integration with capital flows and especially labor flows even exceeding at times those of the new era of hyperglobalization that started in the 1980s (Meissner, 2013). London was the largest financial center at the time and the British pound sterling was the main global currency. However, at the turn of the 20th century the US dollar would start to assert itself and replace the pound's predominant position as the international currency (Eichengreen, 1998).

[1] Consult the database from Jorda, Schularick, and Taylor to get a more detailed overview of the original source material for the interest rate data for each country from 1870 to 2013.

[2] With the notable exception of Spain, which only joined by 1913. See Meissner (2005) for an overview of which countries joined the gold standard in what time period (table 1 in the appendix).

Table 1
Descriptive statistics for the short-term real interest rate from 1871 to 2013 (143 observations per country).

Variable	1871–2013					1871–1913	1914–1944	1945–1973	1973–2013
	Mean	Median	Std. Dev.	Min	Max	Median	Median	Median	Median
AUS	0.021	0.024	0.045	−0.161	0.137	0.035	0.013	0.010	0.030
BEL	0.006	0.022	0.125	−0.640	0.523	0.030	−0.021	0.021	0.021
CAN	0.020	0.018	0.047	−0.131	0.184	0.022	0.015	0.011	0.027
DK	0.030	0.030	0.056	−0.168	0.226	0.046	0.018	0.014	0.025
FIN	0.005	0.029	0.139	−1.178	0.190	0.045	0.040	0.022	0.022
FR	−0.012	0.016	0.095	−0.440	0.194	0.024	−0.067	0.004	0.021
GER	−0.035	0.019	0.300	−2.354	0.166	0.026	0.006	0.015	0.021
ITA	−0.002	0.023	0.157	−1.441	0.228	0.038	0.009	0.010	0.017
JP	0.004	0.026	0.237	−2.338	0.394	0.054	0.040	0.007	0.009
NL	0.014	0.015	0.049	−0.130	0.181	0.024	0.018	0.002	0.021
NOR	0.024	0.023	0.073	−0.349	0.231	0.037	0.019	0.005	0.034
PRT	−0.001	0.016	0.108	−0.538	0.259	0.044	0.001	−0.002	0.001
ESP	0.017	0.018	0.080	−0.332	0.276	0.054	0.027	−0.028	0.011
SWE	0.022	0.021	0.058	−0.315	0.268	0.043	0.034	0.009	0.018
CHE	0.013	0.009	0.056	−0.199	0.228	0.029	0.029	0.002	0.003
UK	0.012	0.022	0.049	−0.177	0.177	0.027	−0.001	0.001	0.031
US	0.021	0.022	0.046	−0.126	0.172	0.044	0.017	0.015	0.013
Average	0.009	0.021	0.101	−0.648	0.237	0.037	0.012	0.007	0.019

Source: Jorda, Schularick, Taylor Macrohistory database (2017). Author's calculation.
The 17 countries in our sample are Australia, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, UK, and the US. We have to make several assumptions and adjustments to the data in order to complete each national time series. Consult the appendix for specific details.

The second period in our sample is the interwar period during which the international monetary system broke down. Several countries like the UK and France left the gold standard during World War I in order finance their war efforts with a combination of expansionary fiscal and monetary policy. As countries later on joined the gold standard again, this was usually done at a flawed exchange rate, given that domestic price levels were inflated dramatically during World War I. As such, Great Britain's pound was certainly overvalued vis-a-vis the French Franc, thus imposing a difficult period of adjustment via internal devaluation on the British economy (Eichengreen, 1998). The roaring twenties were again characterized by extremely high capital mobility with countries in Central and Eastern Europe experiencing very large capital inflows. With the onset of the Great Depression, those credit flows came to an abrupt halt. Austria, Germany, and parts of Eastern Europe experienced financial crises as credit flows that originated from the US were suddenly reversed, the mother of all sudden stops according to Accominotti and Eichengreen (2016). Financial and economic integration broke down with the Great Depression as countries resorted to protectionist measures, followed by World War II (Eichengreen, 1998).

The post-war period was characterized by the Bretton Woods arrangement, which introduced a regime of fixed exchange rates combined with restrictions on capital flows. All major currencies were pegged to the dollar, which in turn was convertible into gold at a fixed rate as well. As the US dollar become the predominant world currency during that time, most European countries were running current account surpluses vis-a-vis the US in order to accumulate dollars while the US in turn was forced to run persistent current account deficits, the so-called Triffin dilemma. Eventually, the system broke down in the early 1970s as the US government also started to run extremely large fiscal deficits caused by the Vietnam War efforts. With the continuous issuance of new currency, the convertibility of dollars into gold was not credible anymore and the fixed exchange rate arrangement was abandoned (Eichengreen, 1998).

Starting in 1973, most countries allowed their currencies to float. Moreover, after the scarring inflationary episode of the 1970s, Central Banks started to manage the macroeconomy by targeting the rate of inflation, commonly adopting the 2% inflation target during the 1990s. As capital became increasingly global again, capital flows and economic integration reached a level last seen at the beginning of the 20th century before World War I. While most countries adopted a flexible exchange rate regime, many countries in Europe started to join the European Exchange Rate Mechanism in the early 1990s, which was a system of pegged exchange rates and the precursor to the common currency area. The adoption of the Euro of course implied that countries would abandon their monetary autonomy as soon as they joined the Eurozone, thus also loosing total control over the determination of domestic interest rates (Eichengreen, 1998). Eight out of the 17 countries in our panel are members of the Eurozone while Denmark has adopted a hard currency peg versus the Euro, implying that Danish monetary policy is also made in Frankfurt. While the Global Financial Crisis of 2008 was certainly one of the largest economic shocks in decades, countries mostly did not repeat the mistakes that were made during the Great Depression. Even though trade flows and capital flows were briefly interrupted, they mostly recovered within a few years. In that sense, the crisis did not seem to represent a regime shift when it comes to the arrangement of the international monetary system.

For the purpose of this paper, we will thus split our dataset that ranges from 1870 to 2013 into four different subsamples, which correspond to the global monetary regimes just mentioned above: The classical gold standard from 1871 to 1913, the interwar period from 1914 to 1944, Bretton Woods from 1945 to 1973, and finally the period of floating exchange rates from 1974 onwards.

5. Methodology

Factor analysis has become a new toolbox within the economics profession that is employed more and more for statistical purposes, especially when it comes to making forecasts for extensive macroeconomic time series data. The general idea is to extract a so-called common latent variable, the factor, from a large number of other variables that share some kind of fundamental relationship (Stock and Watson, 2011). More recently, economists have used dynamic factor analysis to make forecasts about quarterly GDP growth based on hundreds of macroeconomic variables that are available at a higher frequency. The "GDP Nowcast" model by the Atlanta Fed is one practical application of dynamic factor analysis (Giannone, Reichlin, & Small, 2008).

Following the methodology of Gilbert and Meijer (2005), we use time series factor analysis (TSFA) to extract two latent global variables that can explain a large fraction of the variation in national short-term real interest rates. In contrast to static factor analysis, the TSFA also takes the time series dimension into account and allows for the observations to be dependent over time (Gilbert and Meijer, 2005). Moreover, typical factor analysis assumes that all the factors are perfectly uncorrelated and have zero mean, which does not really allow for a natural interpretation of those common factors since within the macroeconomic context economists often encounter growth rates. TSFA was thus suggested by Gilbert and Meijer (2005) as a viable alternative to dynamic factor models. The main difference is that dynamic factor analysis often uses principal components, which again imposes that the factors are uncorrelated. Moreover, the dynamics of the factors are modeled explicitly, commonly in the form of a standard autocorrelation function, thus implicitly making an a priori assumption about the behavior of the dynamic factors (Gilbert and Meijer, 2005). TSFA, on the other hand, seems to be more suited for exploratory factor analysis because it does not impose such a restriction beforehand. Moreover, we are also interested in the economic interpretation of the two factors and not just their dynamic behavior. In TSFA, the observed variables $y_{it}(i = 1, 2, ..., M)$ at each time period t are expressed in terms of k factors θ_{tj}, which are the latent variables, where $k < M$. TSFA assumes that the idiosyncratic error terms ε_t have zero mean and are uncorrelated. The model is given by the following equation:

$$y_t = \alpha + B\theta_t + \varepsilon_t \tag{3}$$

where B is the matrix of the so-called factor loadings. This model thus resembles standard factor analysis except that the observations are indexed by time. We estimate equation (3) with standard quasi Maximum Likelihood using two common factors.

6. A common factor model for national real interest rates

Table 1 contains some descriptive statistics for the real interest rate for our 17 countries in the sample. Most countries have, on average, a short-term real interest rate of about two to three percent from 1871 to 2013, which also corresponds to the average real interest rate during the post Bretton Woods era after 1973. Real interest rates were somewhat higher during the time of the classical gold standard, but lower during the interwar period as well as during Bretton Woods when relatively high inflation rates were putting significant downward pressure on the real interest rate. There are a few extreme outliers in the sample, such as the years of the German hyperinflation during the Weimar Republic, the inflation in Italy during World War II, and the hyperinflationary episode in Japan immediately after Word War II. These periods of severe price increases led to extremely low real interest rates, sometimes in excess of negative 100% for the countries in question during those specific years. As these extreme outliers distort the calculated mean interest rate, we have reported in Table 1 the median interest rate instead for the subperiods we study in our analysis. It should be noted though that the mean and the median are extremely similar for most countries, especially during the post Bretton Woods period, which does not contain any significant inflationary or deflationary episodes.

While TSFA does not require strict covariance stationarity, we perform the common Dickey-Fuller test with two lags and find that the short-term real interest rate is indeed a stationary variable for all countries in our sample, either at the 5% or even at the 1% significance level (see table 2 in the appendix). We also examine the cross-country correlations for the national real interest rate for the entire time period as well as for all the subsamples. Note that with 17 countries we have 136 individual cross-country correlations. We find that the data is well suited for factor analysis as most of the cross-country correlations are positive and high in value. Fig. 2 displays the average cross-country correlation on a decennial basis for the entire time period from 1871 to 2013. For the post Bretton Woods period from 1974 to 2013, we find that the average cross-country correlation for the short-term real interest rate exceeds 66%, followed by an average correlation of about 50% during the interwar period. As expected, real interest rates were significantly less correlated during the

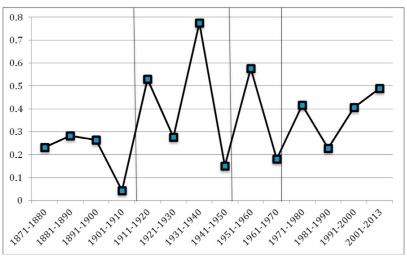

Fig. 2. Average decennial cross-country correlation for the short-term real interest rate from 1870 to 2013.
Source: Author's calculation.

Table 2
Static factor model for the short-term real interest rate.

Static factor analysis (Principal factor method)						
Variable	Factor loadings 1	Factor loadings 2	Factor score 1	Factor score 2	Uniqueness	KMO
AUS	0.629	0.091	0.014	0.080	0.596	0.886
BEL	0.570	−0.304	0.026	−0.160	0.583	0.849
CAN	0.807	0.038	0.099	−0.007	0.347	0.932
DK	0.793	−0.253	0.056	−0.105	0.307	0.908
FIN	0.706	0.136	0.057	0.181	0.483	0.844
FR	0.666	0.546	0.099	0.418	0.259	0.856
GER	−0.049	0.254	0.028	0.064	0.933	0.361
ITA	0.461	0.419	0.033	0.128	0.611	0.903
JP	0.366	0.641	0.036	0.280	0.456	0.747
NL	0.827	−0.042	0.095	−0.002	0.315	0.937
NOR	0.814	−0.303	0.113	−0.166	0.246	0.914
PRT	0.387	0.167	0.028	0.092	0.822	0.703
ESP	0.810	0.017	0.080	0.046	0.344	0.951
SWE	0.869	−0.281	0.172	−0.376	0.166	0.894
CHE	0.763	−0.265	0.069	−0.112	0.348	0.918
UK	0.915	−0.087	0.189	−0.082	0.155	0.934
US	0.796	0.175	0.086	0.133	0.336	0.925
Average	0.655	0.056	0.075	0.024	0.430	0.851
Std. dev.	0.238	0.286	0.049	0.181	0.212	0.139
Minimum	−0.049	−0.304	0.014	−0.376	0.155	0.361
Maximum	0.915	0.641	0.189	0.418	0.933	0.951

Source: Author's calculation.

fixed exchange rate regime of Bretton Woods when capital mobility was very limited (the average correlation is below 28%). More surprisingly, for the period of the classical gold standard we also observe a very low cross-country correlation of only 24%, implying that factors other than capital mobility prevented a convergence of real interest rates during that time, given that capital was relatively mobile across countries (Meissner, 2013).

Table 2 displays the results from a simple static factor model based on the principal factor method with two common factors extracted from the 17 national real interest rates.[3] We can see that the most countries have a very high loading on the first factor. The average value of uniqueness just exceeds 0.4, meaning that almost 60% of the national real interest rate variation can be explained by the two global factors alone. A value of 0.6 is generally considered to be high (Hakkio, 2010). Note though that there is a significant degree of dispersion from country to country. The value for the uniqueness coefficient exceeds 0.9 in the case of Germany, suggesting that less than 10% of the real interest rate variation can be explained by our factor model. The table also displays the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy, a test statistic that measures the proportion of the variance that can be explained by the factor analysis. A value of above 0.8 is generally regarded as high (Hakkio, 2010). Our average KMO value exceeds 0.85, suggesting that the model works relatively well with one notable exception. While the KMO exceeds 0.7 for every other country in the sample, Germany seems to be a major outlier as its KMO value is only 0.36.

Table 3 contains the results from the TSFA model, which also takes the time component into account. We estimate the model for the complete sample as well as for a modified data set in which we have removed all the outliers with interest rates below negative 25% or above 20%, corresponding to periods of extremely high inflation or deflation, respectively.[4] While removing the outliers leads to some changes in the factor scores for a few of the countries in question, neither the coefficient of uniqueness nor the extracted latent factor variables seem to be very sensitive to the outliers in our data set (see Figs. 3 and 4 in the appendix). We therefore choose to leave the time series data of the underlying national real interest rates unchanged for the subsequent analysis without removing any of the extreme values. However, we also include a sensitivity analysis in the subsequent section to justify this approach.

One of the main differences to static factor analysis is that the TSFA methodology as suggested by Gilbert and Meijer (2005) drops the assumption of perfectly uncorrelated factors. While the estimation results from static factor analysis compared to TSFA are relatively similar, the correlation between the two series exceeds 98% for the first common factor and 90% for the second common factor, there are some key differences that make TSFA more suitable for our analysis at hand. Most importantly, TSFA does not impose the restriction that the estimated factors have zero mean, which would make a macroeconomic interpretation more difficult. In what follows, we will therefore mainly rely on the results from TSFA for the reasons outlined above.

We have previously extracted the two common global factors for the entire time period from 1871 to 2013 using TSFA. We now follow the approach of Hakkio (2010) who uses two common factors to explain global inflation rate dynamics. We estimate two separate regressions with our two factor variables, including an idiosyncratic error term. We regress each national real interest rate against the first common factor, and in a separate regression we regress the interest rate against both the first and the second common factor:

[3] Inspection of the Eigenvalues suggest that we should not use more than two common factors.
[4] Consult the appendix for specifics on how the outliers were removed from the data.

Table 3
Time series factor model for the short-term real interest rate.

Variable	Complete data set			Outliers removed		
	Factor score 1	Factor score 2	Uniqueness	Factor score 1	Factor score 2	Uniqueness
AUS	0.026	0.010	0.571	0.012	0.020	0.566
BEL	0.078	−0.020	0.621	0.048	0.007	0.586
CAN	0.034	0.011	0.340	0.016	0.026	0.330
DK	0.048	−0.008	0.299	0.047	−0.001	0.291
FIN	0.089	0.021	0.524	0.031	0.033	0.477
FR	0.040	0.070	0.153	−0.013	0.076	0.260
GER	−0.043	0.058	0.952	0.004	0.025	0.845
ITA	0.047	0.071	0.651	0.009	0.053	0.372
JP	0.034	0.152	0.529	−0.008	0.065	0.581
NL	0.039	0.005	0.315	0.030	0.013	0.318
NOR	0.065	−0.016	0.229	0.068	−0.009	0.188
PRT	0.035	0.011	0.871	0.012	0.025	0.840
ESP	0.062	0.010	0.357	0.036	0.028	0.365
SWE	0.054	−0.009	0.167	0.049	−0.001	0.159
CHE	0.046	−0.007	0.368	0.042	0.002	0.368
UK	0.044	0.004	0.151	0.032	0.017	0.156
US	0.032	0.014	0.339	0.008	0.032	0.299
Average	0.043	0.022	0.437	0.025	0.024	0.412
Std. dev.	0.027	0.042	0.231	0.021	0.023	0.204
Minimum	−0.043	−0.020	0.151	−0.013	−0.009	0.156
Maximum	0.089	0.152	0.952	0.068	0.076	0.845

Source: Author's calculation.

$$r_{it} = \alpha + \lambda_{1i} {}^* f_{1,it} \tag{4}$$

and

$$r_{it} = \alpha + \lambda_{1i} {}^* f_{1,it} + \lambda_{2i} {}^* f_{2,it} + \varepsilon_{it} \tag{5}$$

Table 4 summarizes the results from the regressions as given by equations (4) and (5), respectively. The model seems to work relatively well when we estimate it for the entire time period from 1871 to 2013. The R^2 of the regression based on one single factor is extremely high, well exceeding 50% for most countries in our data set. Adding the second factor to the regression improves the average goodness of fit to close to 60%. While the second factor adds some explanatory power, most of the variation in domestic real interest rates over time can be solely explained by the first common factor. However, there are some important differences, both by country as well as by subperiod. Germany seems to be the most extreme outlier in our sample as the two common factors have very little explanatory power: The R^2 of the regression incorporating both factors is below 6% when we consider the entire time period.

Table 4
R^2 of a regression of the national real interest rate against the first common factor (column 1) and against both factors (column 2) for each time period.

	1871–2013		1871–1913		1914–1944		1945–1973		1974–2013	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
AUS	0.391	0.445	0.004	0.125	0.550	0.577	0.699	0.707	0.793	0.796
BEL	0.372	0.401	0.235	0.237	0.458	0.474	0.042	0.455	0.622	0.654
CAN	0.626	0.684	0.367	0.506	0.738	0.834	0.751	0.805	0.773	0.829
DK	0.713	0.734	0.569	0.610	0.780	0.785	0.344	0.478	0.604	0.613
FIN	0.465	0.492	0.464	0.530	0.485	0.495	0.285	0.815	0.831	0.831
FR	0.320	0.940	0.011	0.249	0.444	0.928	0.368	0.973	0.811	0.853
GER	0.013	0.056	0.460	0.500	0.052	0.125	0.157	0.273	0.647	0.743
ITA	0.148	0.385	0.337	0.352	0.093	0.329	0.116	0.623	0.826	0.857
JP	0.069	0.543	0.032	0.072	0.411	0.522	0.086	0.764	0.491	0.491
NL	0.696	0.708	0.532	0.532	0.815	0.834	0.295	0.409	0.749	0.752
NOR	0.760	0.815	0.720	0.747	0.800	0.866	0.354	0.650	0.754	0.829
PRT	0.121	0.134	0.068	0.077	0.098	0.191	0.021	0.030	0.453	0.484
ESP	0.648	0.664	0.332	0.411	0.775	0.778	0.223	0.366	0.795	0.803
SWE	0.848	0.873	0.690	0.796	0.888	0.900	0.679	0.876	0.732	0.751
CHE	0.643	0.662	0.478	0.481	0.892	0.893	0.233	0.312	0.280	0.332
UK	0.870	0.877	0.540	0.546	0.949	0.949	0.786	0.792	0.889	0.889
US	0.577	0.689	0.101	0.599	0.724	0.812	0.506	0.749	0.508	0.751
Average	0.487	0.594	0.349	0.433	0.585	0.664	0.350	0.593	0.680	0.721
Std. dev.	0.268	0.243	0.230	0.212	0.285	0.257	0.243	0.248	0.161	0.152
Minimum	0.013	0.056	0.004	0.072	0.052	0.125	0.021	0.030	0.280	0.332
Maximum	0.870	0.940	0.720	0.796	0.949	0.949	0.786	0.973	0.889	0.889

Source: Author's calculation.

Somewhat surprisingly, the average R^2 is relatively low during the period of the classical gold standard, just below 45% on average, despite the fact that this was an era characterized by relatively high economic integration and also highly mobile capital flows. There are again a few outliers in the sample. France, Japan, and Portugal are the countries for which the first factor has little to no explanatory power for variations in the national short-term real interest rate as the value of the R^2 is only 1%, 3%, and 7%, respectively. Furthermore, adding the second factor to the regression seems to add little explanatory power as it improves the goodness of fit only at the margin, with France being the notable exception for which the R^2 increases to about 25% once the second factor is added as an independent variable.

Our model can explain a larger part of the variation during the interwar period as the average R^2 increases to 59% using one factor, and 66% using both factors as independent variables. Again, the large outlier is Germany for which the two international factors have almost no explanatory power for variations in the domestic real interest rate. However, this is hardly surprising as the country experienced many idiosyncratic shocks during that time period. Germany was certainly affected the most by the repercussions of World War I, which resulted indirectly in the political instability of the Weimar Republic as well as the Weimar hyperinflation. Furthermore, the country also suffered extremely during the Great Depression when the unemployment rate soared to more than 25%, ultimately culminating in the election of the Nazi regime. As such, it is not surprising that the two international factors have little power in explaining variations of the real interest rate for Germany. Similarly, the short-term real interest rate in some other European countries, such as Italy and Portugal, also seems to be determined mostly by domestic variables as the two global factors can explain only a small part of the variation during that period. However, the factor analysis seems to be well suited for most of the countries in the sample during the interwar period, with the regression of the UK real interest rate against the first global factor leading to the highest R^2 in the sample, exceeding 94%.

As expected, the model seems to break down somewhat during Bretton Woods when capital mobility was very limited as a result of the fixed exchange rate arrangement as the average R^2 decreases to only 35%. The first factor now explains relatively little of the variation in domestic real interest rates. Somewhat surprisingly, the second factor now adds a lot of explanatory power to the analysis, raising the average R^2 to almost 60%. The Bretton Woods period is thus the only subperiod in the sample when a much larger part of the variation can be explained by the second global factor instead.

Unsurprisingly, the model works extremely well for the period of floating exchange rates post Bretton Woods, an era when global financial markets become increasingly integrated and capital mobility is high. The first factor alone can now explain, on average, more than 68% of the real interest rate variation for most countries in the sample. Taking the example of the US during the post Bretton Woods period, Fig. 3 displays the scatterplot for the regression of the US short-term real interest rate against the first global factor estimated with TSFA. With an R^2 of above 50%, more than half of the variation of the US real interest rate can be explained by the first global factor alone. Adding the second factor to the regression improves the goodness of fit to about 75% for the US whereas the average R^2 for all 17 countries in the sample increases to above 72% using both common factors.

Using the estimated factor scores for the first common factor, the TSFA model also allows us to calculate projections for the real interest rate for each individual country. Fig. 4 displays the factor projection for the first factor against the US real interest rate for the post Bretton Woods period. We can see that the projection mirrors with a relatively high degree of accuracy the actual movements of the US real interest rate, both in the short-run as well as in the long-run. The factor projection picks up quite well the quite sudden spike in real interest rates in the early 1980s when Fed chairman Paul Volcker tightened monetary policy dramatically to choke off the inflationary episode of the prior decade. Moreover, the first global common factor can also explain the large secular downward trend of the US real interest rate since the late 1980s, a phenomenon that has been dubbed secular stagnation by Larry Summers and others (Summers, 2014). The commonality of the downward trend across countries, and the fact that the first global factor can explain the pattern quite well seem to suggest that there are global forces at work that have depressed real interest rates across countries in recent decades. In that sense, any theory of secular stagnation should probably look beyond domestic variables and US specific forces and incorporate international macroeconomic features as well.

Using the average country score, we standardize the first factor variable extracted from our TSFA and plot it versus a measure a of the

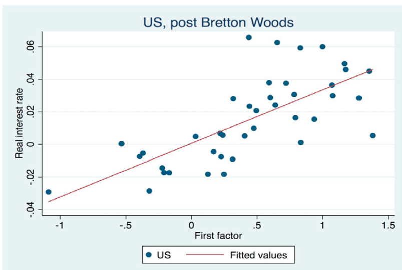

Fig. 3. Scatterplot of the first time series factor vs. the U.S. real interest rate, 1973–2013.
Source: Author's calculation.

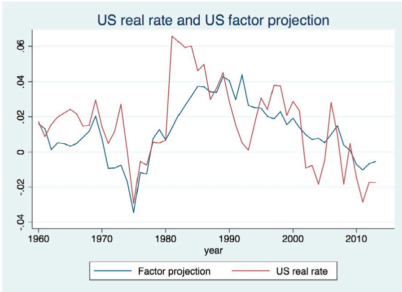

Fig. 4. Factor projection and actual value of the short-term US real interest, 1960–2013.
Source: Author's calculation.

global short-term real interest rate, which we calculate as the real GDP-weighted average of all 17 national real interest rates in our sample. Given the size of the US economy, ranging from about 20% of total GDP in our data set in the late 19th century to more than 40% in 2013, US interest rates have obviously a disproportionate weight in determining the global real interest rate: The correlation between the US interest rate and our global GDP-weighted real interest rate exceeds 90% post Bretton Woods.

Fig. 5 shows that the standardized first common factor estimated with TSFA seems to be a very good proxy for the global short-term real interest rate. The correlation between the first factor and the cross-country weighted average real interest rate is extremely high, with a value of more than 96% during the period of floating exchange rates, followed by a value of more than 78% during the classical gold stand, which correspond to the two global monetary regimes when capital mobility was the highest (table 4 in the appendix). Most importantly, the first common factor picks up most of the short-run variations as well as all of the long-term secular trends of the global real interest rate for the more than 140 years of data. Of particular interest is the dramatic spike in the global real interest rate following the 1970s and the subsequent long-term secular decline that started in the late 1980s.

We will elaborate on the interaction between the two global factors and the national business cycle later on. Suffice it to say that any theory of secular stagnation must also incorporate international macroeconomic trends that have affected most advanced economies in recent decades. More recently, some authors have emphasized that an increase in markups can explain the simultaneous decline in the global labor share of income as well as the downward trend in real interest rates (Eggertson et al., 2018). On the other hand, a large part of the secular stagnation literature stresses a combination of rising inequality, low productivity growth, and declining labor force growth (Summer 2014). Needless to say, since most of these trends have been going in the same direction across most advanced economies, we expect many of these forces to interact with the first common global factor for national real interest rates that we have estimated above.

7. Robustness checks and sensitivity analysis

In this section, we perform several robustness checks in order to gauge the accuracy of the TSFA when applied to our data. One of the main concerns is that some of the extreme outliers might affect the estimation of our factor model and thus distort some of the results found above. More specifically, some countries in our sample, such as Germany, experienced severe inflationary episodes during the time period under

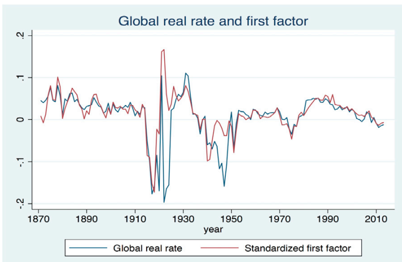

Fig. 5. Standardized first common factor and global real interest rate, 1871–2013.
Source: Author's calculation.

consideration (see Table 1). With the annual inflation rate well exceeding 100% in Germany in 1923 during the Weimar hyperinflation, the effective real interest rate becomes quite meaningless for that specific year. The same can be said for other highly inflationary episodes, such as the period during World War II in Italy and post World War II Japan. While there is a certain asymmetry between large inflationary episodes and deflationary episode, hyperinflations have been observed occasionally whereas price declines rarely exceed 15% annually even during the Great Depression, large deflations correspond to extremely high positive real interest rates wheares hyperinflations correspond to excessive negative real interest rates. To address this problem, we estimate the time series factor model after removing all the outliers from the sample. We perform in total three different diagnostic tests as a robustness check to determine whether our results hold up in general. More specifically, we use the following procedures: First, we apply the TSFA to the same data and extract only one common global factor from all national real interest rates instead of extracting two common factors. Second, we estimate the model with two factors, but using data for the long-term real interest rates for each country instead of using the short-term rate. Third, we estimate the model with two common factors as above, but only after having removed all the extreme outliers from the data.

Table 6 presents contains the summary statistics for the estimated factor variables we have extracted from the data based on the different assumptions just mentioned above. First, the model is quite insensitive to whether we extract only one common global factor from the underlying national real interest rates or two factors instead. The correlation for the first factor between the two different approaches exceeds 98% and the underlying factor scores for each year are almost identical. This gives us some confidence that the estimation of the first common factor variable was performed without any significant bias. Second, we estimate the model using the long-term real interest rate for each country presented in the Jorda, Schularick, and Taylor database (2017) instead of using the short-term interest rate. While the correlation for the two factors is extremely high, exceeding 98%, the first common factor is shifted upwards when applied to the long-term interest rate data instead. This is hardly surprising since the first common factor can be now interpreted as an approximation of the long-term global real interest rate instead, which a priori should be highly correlated with the short-term real interest rate but assume a higher value during most time periods, depending on the size of the term premium for each year. Third, we estimate the factor model after removing all the outliers. While the first factor variable seems to be basically unaffected, the second factor appears to be much more sensitive to extreme values in the data. The correlation for the second common factor between the original data and the data without the outliers is only 72%. Since most of the outliers correspond to excessive negative real interest rates during inflationary episodes, the second factor variable basically shifts upwards for the entire time period after having removed the outliers (see Fig. 4 in the appendix).

While the interpretation of the first common factor variable in our model is relatively straightforward, being an approximation of the global real interest rate, we do not have such a natural explanation for the second common factor in our model. For now, we can only speculate as to why the second factor variable adds significant explanatory power in explaining national real interest rates, especially during the Bretton Woods time period of limited capital mobility, and why eliminating the outliers in our data leads to a significant shift in the second factor variable. Suffice it to say that we choose to extract two factors from the underlying data in our analysis above because the second factor does lead to a significant improvement in the goodness of fit for some of the countries in the sample, even if the second factor variable does not have a straightforward natural interpretation in itself. While one avenue for further research could be a deeper investigation into what macroeconomic variables exactly determines the second common factor, this is for now outside the scope of this investigation. However, we will see in our Panel-VAR estimation below that both factor variables have a significant impact on several key business cycle variables on the national level.

8. An error correction approach

While contemporaneous correlations are certainly of interest, the first global factor also seems to be helpful in predicting future national real interest rates. More specifically, consider an error correction model (ECM) of the national real interest rate for each country and the first global factor of the following type:

$$\Delta\, r_t = \beta_{10} + \beta_{11}\Delta r_{t-1} + \gamma_{11}\Delta f_{t-1} + \alpha_1(r_{t-1} - \lambda_0 - \lambda_1 f_{t-1}) + u_{1t} \tag{6}$$

and

$$\Delta\, f_t = \beta_{20} + \beta_{21}\Delta F_{t-1} + \gamma_{21}\Delta r_{t-1} + \alpha_2(r_{t-1} - \lambda_0 - \lambda_1 f_{t-1}) + u_{2t} \tag{7}$$

The error correction term $(r_{t-1} - \lambda_0 - \lambda_1 f_{t-1})$ helps to predict future values of $\Delta\, r_t$ and $\Delta\, f_t$. We estimate this model for the entire time period as well as for all the four subperiods of the sample. The results are summarized in Table 5 in the appendix. In the ECM, both the

Table 5
Summary statistics for the factors based on different data assumptions.

	Originial data		Outliers removed		Factor model with long-term interest rates		Original data, 1 factor
	Factor 1	Factor 2	Factor 1	Factor 2	Factor 1	Factor 2	Factor 1
Average	0.378	−0.233	0.43	0.196	0.501	−0.114	0.365
Median	0.418	0.002	0.44	0.409	0.533	0.138	0.427
Standard deviation	1.018	1.08	1.024	1.047	1.016	1.08	1.02
Correlation to the factor based on original data			0.981	0.72	0.983	0.989	0.996

Source: Author's calculation.

speed of adjustment coefficient α_1 as well as the coefficient of the cointegrating equation λ_1 are supposed to assume negative values if there exists an equilibrium relationship between the two variables.

As expected, our findings show that both coefficients are negative for all countries in the sample. The speed of adjustment coefficient is highly statistically significant for most countries, with the exception of France, Germany, Spain, and the UK, if we estimate the ECM model for the entire period from 1871 to 2013. The regression results thus suggests that if the national real interest rates is greater than the global real interest rate, as measured by the first common factor f_t, it is the national real interest rate that tends to decline in the subsequent period. The speed of adjustment coefficient α_1 is relatively high, suggesting that equilibrium is achieved within a couple of years at most. The estimated half-life, calculated as $\ln(0.5)/\ln(1+\alpha_1)$ thus implies that any disequilibrium between the national real interest rate and the first common global factor is eliminated within just a couple of years for most countries in the sample, if not within less than a year. Note that it is during the time period of flexible exchange rates and increasing capital mobility after 1973 that the half-life time is the smallest, on average, thus indicating a greater tendency for real interest rates to converge towards equilibrium. During the period of Bretton Woods, on the other hand, the half-life is considerably higher for many of the countries in the sample, thus suggesting that national interest rates were significantly less responsive to the first international factor than during other periods.

Moreover, the model also suggests that it is the national real interest rate, which makes the adjustment towards equilibrium instead of the global real interest rates as approximated by the first common factor. This makes sense insofar as most countries in the sample are not large enough in size and are thus not expected to have a significant impact on the global real interest rate, the US economy being the notable exception. While the model also seems to perform reasonably well during the other monetary regimes, it is again the Bretton Woods era that seems to be somewhat of an outlier. While the speed of adjustment coefficient has the right sign for most countries, it is only statistically significant for 10 out of the 17 economies in the sample (one should note though that sample size might be an issue here with only 29 observations for each regression for the Bretton Woods period whereas the other subperiods are longer and thus contain more annual observations). All in all, the ECM model shows that the first common factor acts as an attractor to national real interest rates, with the notable exception for the period of fixed exchange rates during Bretton Woods. As was to be expected, the global real interest rate thus exerts a force of attraction on national real interest rates that divert from the equilibrium value, especially in today's period of high capital mobility.

9. Nominal interest rates and inflation rates

As outlined in equation (2), the real interest rate is of course a combination of two nominal variables, namely the nominal interest rate minus the rate of inflation. Any variation in real interest rates can thus be decomposed into variations of the two nominal variables using the following formula below:

$$Var(r) = Var(i) + Var(\pi) - 2^*Cov(i,\pi) \tag{8}$$

We have found above that national real interest rates share two common factors with the first common factor being able to explain a significant share of the variation in domestic real interest rates, depending on the time period under consideration and the country in question. Based on equation (6), if we can explain a large part of the variation in short-term real interest rates (r), then we must also be able to explain a large part of the variation in both the short-term nominal interest rate (i) and the rate of inflation (π) using our time series factor analysis.

Fig. 6 displays the decennial correlation of both variables from 1870 to 2013. One can see that the rate of inflation was highly correlated across countries during the classical gold standard, as was to be expected. While the cross-country correlation for nominal interest rates was significantly lower by the start of the period, it edged upwards over time and reached a high of close to 50% by the beginning of the 20th century. The correlation coefficient for both variables decreases during the interwar period as well as during the time of Bretton Woods, which is again in line with our expectations, given that global economic and financial integration was dramatically lower during the postwar period. Finally, cross-country correlations both for the nominal interest rate as well as for the rate of inflation have increased significantly again in recent decades during the period of floating exchange rates.

We also apply the TSFA for both variables separately and Table 6 below summarizes the coefficient of uniqueness for each country from our estimation. Similar to our results for the real interest rate above, we find that we can explain a large part of the variation for national nominal interest rates as well as for national inflation rates using our time series factor model with two common factors extracted from the underlying data. The average value of uniqueness in our sample is 0.31 and 0.43 for the two variables, respectively.

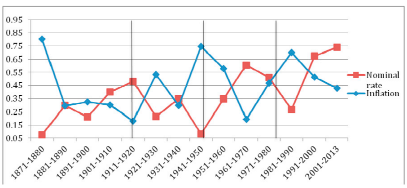

Fig. 6. Average decennial cross-country correlation for the short-term nominal interest rate and inflation, 1871–2013.
Source: Author's calculation.

Again, Germany is the biggest outlier due to the country-specific shocks that have occurred at the beginning of the 20th century. While it is somewhat surprising to find such a high degree of communality between national inflation rates, this finding is in line with prior research, such as Haikko (2010). As most modern Central Banks have adopted a formal or informal 2% inflation target in recent decades, one would not necessarily expect national inflation rates to be codetermined by global factors, especially in the case of large economies like the US where the tradable sector is a smaller share of total ouput. In reality, however, more recent research has emphasized that national inflation rates do in fact respond to global economic conditions and show strong co-movement across countries. Borio and Filardo (2007), for example, find that proxies for global economic slack are significant in traditional inflation rate equations. More recently, Haikko (2010) has shown that two common global factors have significant explanatory power for national inflation rates. Similarly, we find a high degree of communality between national real interest rates, which mechanically implies that both the nominal rate of interest as well as the inflation rate must share common latent factor variables as well.

10. Global business cycle conditions determine the dynamics of the common international factors and vice-versa

In what follows, we use a Panel-VAR model in order to determine the interaction between our estimated common global factors extracted from the national real interest rates and the national business cycle. The VAR methodology has the obvious advantage of including dynamic interactions between our key macroeconomic variables of interest. While many papers estimate a global VAR model using GDP-weighted averages of several macroeconomic variables as a proxy for global economic conditions, there are severe disadvantages of such an approach, especially given our data at hand. Most importantly, the number of observations is simply insufficient using annual data for the number of parameters we want to estimate in the model, or in statistical parlance, the model would suffer from insufficient degrees of freedom. The advantage of the Panel-VAR approach, on the other hand, is that it greatly increases the statistical power and efficiency of the analysis. One key disadvantage of the model, however, is that it imposes the pooling restrictions across countries, which means that we disregard cross-country differences in the estimated dynamic relationship by design. Moreover, we also impose that every country has equal weight. The first assumption is not that problematic and can be defended on the grounds that a panel approach might help us uncover systematic dynamic macroeconomic relationships, which might otherwise be obscured by country-specific effects if we were to estimate the VAR model individually for each country in our panel (Gavin and Theodorou, 2005). The second assumption, on the other hand, is somewhat more problematic. There is no doubt that the global business cycle has historically been dominated by a few countries that are large in economic size compared to the rest of the world. As such, the US still accounts for about 25% of world GDP in 2016 and more than a third of global stock market capitalization in 2016 (World Bank, 2016) and these shares are even higher in our panel of 17 advanced economies. While it is certainly of interest to document the extent to which one or several large countries dominate the global business cycle, we are more interested in the average marginal effect across our panel.

Based on the Jorda, Schularick, and Taylor database (2017), we include the following macroeconomic variables in our Panel-VAR model: the log difference of real GDP (Δy), the log difference of the consumer price index (Δcpi), the level of the short-term interest rate (i), the log difference of nominal stock prices $\Delta stock$, the log difference of nominal house prices (Δhp) based on Knoll, Schularick, and Steger (2017), the log difference of nominal private credit (Δc), and the investment to GDP ratio (iy). For later periods, we also add the gross capital share (cap share) based on the Bengtsson-Waldenström database (2015) as a measure of inequality. All these variables are endogenous in our system and reflect national macroeconomic conditions. Our model thus includes some key monetary variables (inflation, nominal interest rates, and credit), asset prices (nominal stock prices and house prices) as well as three real outcomes, which

Table 6
Uniqueness coefficient from the TSFA for the short-term nominal interest rates and the rate of inflation.

	Nominal rate	Inflation
AUS	0.193	0.601
BEL	0.048	0.647
CAN	0.123	0.331
DK	0.155	0.256
FIN	0.284	0.536
FR	0.082	0.179
GER	0.917	0.979
ITA	0.177	0.634
JP	0.943	0.502
NL	0.178	0.320
NOR	0.081	0.254
PRT	0.157	0.811
ESP	0.482	0.310
SWE	0.143	0.154
CHE	0.869	0.352
UK	0.155	0.125
US	0.328	0.299
Average	0.313	0.429
Std. dev.	0.294	0.241
Minimum	0.048	0.125
Maximum	0.943	0.979

Source: Author's calculation.

are GDP growth, the investment share as well as the functional distribution of income. Finally, we also include two exogenous variables in the model, f_1 and f_2 (including their first lag), which are the two contemporaneous common global factors previously estimated with TSFA. The two factors are assumed to be exogenous as a result of the small-country assumption: While we expect the factors to affect the national business cycle and domestic macroeconomic variables, we do not expect there to be a feedback loop since small countries should have little to no influence on the global equilibirium real interest rate. National business cycle variables should thus have no effect on our two estimated factor variables. Obviously, as argued above, this assumption is surely violated for the US economy, given its relative economic size, but it might be a good approximation for most of the other countries in the sample.

One common problem that one encounters in macroeconomic time series data is the existence of unit roots, which can lead to spurious regressions. For that reason we have expressed most of our variables in logarithmic first differences. We test for stationarity in our data using the Im-Pesaran-Shin unit-root test (Im, Hashem Pesaran, & Shin, 2003) for heterogeneous panels. We do find strong evidence that our variables are indeed stationary across cross-sectional units (we can reject the null hypothesis of unit roots at the 1% level).

We estimate the following Panel-VAR model:

$$Y_{i,t} = A(L)Y_{i,t} + B_1X_t + B_2(L)X_t + \varepsilon_{i,t} \tag{9}$$

with

$$Y = [\Delta y,\ \Delta cpi,\ i,\ \Delta stock, \Delta hp, \Delta c,\ iy,\ cap\ share]\ and\ X = [f_1, f_2] \tag{10}$$

The system is estimated using the so-called “Helmert procedure suggested by Arellano and Bover (1995). Pooling data imposes the restrictions that the underlying structure is the same for each cross-sectional unit in the system. While including fixed effects is one way to overcome this problem, mean-differencing also creates bias as the fixed effects are correlated with the regressors due to lags of the dependent variables. The “Helmert procedure” is a transformation that only removes the forward mean and thus preserves the orthogonality between transformed variables and lagged regressors, which can be used as instruments to estimate the coefficients by System GMM (Love and Zicchino, 2004). This method also has the advantage that estimation is feasible with an unbalanced panel, as is the case with our data.

It is well known that the particular ordering of the variables in a VAR model can be important. The identifying assumption, according to Love and Zicchino, 2004, is that the variables that come earlier in the ordering affect the following variables contemporaneously, as well as with a lag, while the variables that come later affect the previous variables only with a lag. One can thus say that the variables that appear earlier in the system are more exogenous while the variables that appear later are more endogenous. We follow closely the approach used by Goodhart and Hofmann (2008) who estimate a similar system. The ordering of the first three variables (GDP growth, inflation, and interest rates) is standard in the monetary transmission mechanism whereas the ordering of the remaining variables is somewhat arbitrary. While the investment share and the capital share are the most endogenous in our system, robustness checks suggest that the particular ordering of the variables does not have a substantial effect on our results.

11. Empirical results of the Panel-VAR model

We estimate equation (7) with System GMM, using lags one to three as instruments for the estimation procedure. Based on the Akaike and Schwarz information criteria, we choose to estimate the Panel-VAR model with only one lag of the endogenous variable.[4] We include in the model the first two common global factors estimated by TSFA as a contemporaneous exogenous variable as well as their first lag. We estimate the system for the entire sample from 1870 to 2013 and for the four different subsamples, which correspond to the global monetary regimes mentioned above. We also test for the stability of our Panel-VAR model and find that all the Eigenvalues lie inside the unit circle, meaning that the system is stable and that there is no obvious misspecification in our estimation method (Abrigo and Love, 2016).

[4]As usual, there is a tradeoff between efficiency of the estimator and data loss. While using more lags as instruments increases the efficiency of the estimation, it also leads to more data loss, which is problematic since our time dimension is not that large because we have annual data only. For that reason we chose to use three lags as instruments for the estimation of the Panel-VAR system.

The regression results are summarized in table 6 in the appendix and the findings are generally in line with our prior expectations. We are mostly interested in the coefficients of the contemporaneous and lagged common global factors f_1 and f_2, which we have included as exogenous variables in the system, while all the national macroeconomic variables are endogenous as outlined above. We use a simple Wald statistic to test for joint significance for each common global factor and its first lag in all of the eight equations in the Panel-VAR model. In line with our priors, both global factor variables have a statistically significant effect on the entire range of national macroeconomic variables that we have included in our specification. While this finding is generally robust across macroeconomic regimes, it seems like the global factors have increased in importance in the post Bretton Woods period with the liberalization of capital flows internationally, which again is in accordance with standard macroeconomic theory. As economic integration increases, business cycle synchronization rises as well and asset price changes are increasingly correlated on a global level (Jordà, Schularick, Alan, & Taylor, 2017).

The Wald test indicates that the first common global factors is statistically significant at the 1% or 5% significance level in affecting real GDP and inflation for all subperiods in our analysis, with the exception of the period during the classical gold standard. While the second common factor seems to play a lesser role during most time periods, it is statistically significant at the 1% level in affecting all domestic macroeconomic variables besides consumer prices and credit growth during the Bretton Woods period. This supports our findings above that the second common factor variable played a more prominent role during the period of fixed exchange rates from 1945 to 1973. We also find that the first common factor is statistically significant in affecting asset prices, both with respect to nominal stock prices and nominal house prices, as well as credit growth and the investment share of GDP. This result holds up for all the subperiods with the exception of the classical gold standard when the first common factor does not seem to have a statistically significant effect on any of those variables. The capital share, on the other hand, seems to be largely unaffected by our two common factor variables, at least during the period of floating exchange rates after 1973.

While many of the aforementioned results generally hold across the different subperiods in our sample, one should note that the two common factor variables increase in economic significance during the post World War II period, and especially after the end of Bretton Woods. This finding is consistent with the general result that national business cycles have become less insulated in recent decades, a consequence of higher global interconnectedness of asset markets and financial markets in general, as capital mobility has risen significantly (Jordà et al., 2018). Consequently, global real interest rates seem to have more of a direct effect on national business cycle variables as economic integration has increased across our panel of advanced economies. One should note, however, that within our Panel-VAR framework we can only estimate the average marginal effects across our panel, which thus hides cross-country heterogeneity by assumption(See Table 7).

12. Discussion

The standard neo-keynesian model posits that changes in the real interest rate affect a range of macroeconomic outcomes, from nominal quantities such as monetary aggregates and stock prices to real outcomes like GDP (Sørensen & Whitta-Jacobsen, 2005). Most DSGE models assume that the real interest rate alters consumption behavior by affecting the intertemporal budget constraint. A rise in the interest rate increases the opportunity cost of present consumption and thus tends to push consumption into the future. Interest rate changes also affect credit and lending conditions in general. Moreover, interest rates also have an impact on asset prices, both stocks and housing, by changing the net present value of all future cash flows (Ubide, 2017). Similarly, interest rate changes alter investment behavior via Tobin's Q theory of investment: A lower rate of interest rate decreases the market value for physical capital compared to its replacement value, thus making it less attractive for firms to invest. Within the standard neo-keynesian model, the rate of interest is thus one of the most important macroeconomic variables because it has a direct effect on many key business cycle variables (Sørensen & Whitta-Jacobsen, 2005). Our results suggest that the global real interest rate plays a more important role in explaining variations of national real interest rates than what is commonly assumed. Given the importance of the real interest rate of for a range of macroeconomic outcomes, it is ultimately not surprising that we also find that our two common global factors affect the national business cycle throughout the same range of macroeconomic variables. Moreover, our Panel-VAR analysis suggests that both time series factors affect the national business cycle via the standard neo-keynesian transmission mechanism: A rise in global real interest rates is associated with a more contractionary stance of global macroeconomic conditions, thus negatively affecting national business cycle variables, such as real GDP growth, the rate of inflation, stock prices, and credit growth.

While we established the importance of the two common factors as exogenous forces in determining national business cycle variables, our identifying assumption is that most countries are generally too small to affect global equilibirum real interest rate in any meaningful way. Even though this assumption makes sense for most countries in our sample, there is no doubt that the US macroeconomic conditions might have an impact on global factor prices, given the size of the US economy and the size of American financial markets as a share of global GDP. However, given the exogeneity assumption, we were unable to model any dynamic interdependencies and feedback loops between our estimated common global factors and the US business cycle in our Panel-VAR specification as estimated above. It thus remains an open question and avenue for further research to what extent US macroeconomic conditions affect our estimated global factor variables.

13. Conclusion

Using a time series factor model, we have estimated two common global factors for the short-term real interest rate for 17 advanced economies from 1871 to 2013. Our findings indicate that our two common factors alone can explain a significant part of the variation of national real interest rates. As was to be expected, the time series factor anlaysis performs better during times of high capital mobility, such as the classical gold standard as well as post Bretton Woods when capital flows would have the tendency to equalize risk-adjusted returns across countries. During the Bretton Woods period, on the other hand, limited capital mobility implied that idiosyncratic factors on the country level were more important in the determination of national real interest rates than global trends. While the first common factor we have estimated can be interpretated as the global short-term equlibrium real interest rate, the interpretation of the second common factor is not as straightforward. Moreover, it is somewhat surprising that the second common factor adds a lot of explanatory power during the period of Bretton Woods when the global real interest seems to be of lesser importance for the determination of national interest rates.

Table 7
Wald test of joint significance for the contemporanoeus and lagged common global factors f_1 and f_2 in our Panel-VAR model.

	1871–2013		1871–1913		1914–1944		1945–1973		1974–2013	
	f_1 and L. f_1	f_2 and L. f_2	f_1 and L. f_1	f_2 and L. f_2	f_1 and L. f_1	f_2 and L. f_2	f_1 and L. f_1	f_2 and L. f_2	f_1 and L. f_1	f_2 and L. f_2
Δy	0.217	0.189	0.974	0.103	0.020	0.006	0.005	0.000	0.000	0.138
Δcpi	0.000	0.713	0.000	0.229	0.000	0.523	0.000	0.263	0.000	0.102
ir	0.000	0.001	0.632	0.407	0.000	0.597	0.000	0.004	0.000	0.001
$\Delta stock$	0.000	0.052	0.181	0.074	0.000	0.001	0.000	0.000	0.000	0.000
Δhp	0.158	0.195	0.122	0.047	0.001	0.017	0.911	0.000	0.014	0.169
Δc	0.009	0.273	0.008	0.174	0.000	0.002	0.000	0.141	0.000	0.729
iy	0.069	0.400	0.281	0.020	0.749	0.009	0.039	0.000	0.000	0.557
cap share	0.037	0.054	–	–	0.000	0.001	0.000	0.000	0.422	0.128

Source: Author's calculation.

Unfortunately, we do not have a good explanation for why the second factor becomes of such significance during Bretton Woods when capital flows were much more restricted while during the other periods it adds, on average, much less explanatory power.

Using an error-correction model, we have determined that the first common factor tends to act as an attractor for national real interest rates, meaning that a national real interest rates above equilibrium would tend to decline in the subsequent period while a real interest rate below equilibrium would tend to increase. This finding supports the small-country assumption, which implies that interest rates are mostly set by financial conditions in international capital markets.

In our Panel-VAR model, we show that our two common global factor variables are also important determinants of the national business cycle, a finding that is hardly surprising. Especially the first common factor, being an approximation of the global short-term real interest rate, has become more important in determining a set of domestic macroeconomic variables ranging from real GDP growth to monetary variables, such as inflation and credit growth, and even asset prices. The implications are straightforward and also quite important from a policy-making point of view. It seems like during times of high capital mobility, small countries might have increasing difficulties to insulate themselves from the global business cycle and variations in global real interest rates. While most neo-keynesian models still assume that Central Banks have a sufficient degree of control over the domestic real interest rate, at least in the short to medium run, our analysis casts some doubt on this widely-held assumption. Given that about 70% of the variation in national real interest rates can be explained by our two common global factors alone, most Central Banks might have no choice other than to set the domestic interest rate in accordance with the equilibirum determined by international capital markets. The case of Sweden is quite illuminating. While the Riksbank is said to have monetary autonomy in theory, in practice the Swedish interest rate tends to follow the policy rate of the ECB almost one to one, which in turn usually follows the policy rate set by the Federal Reserve with a lag of about one to two years, consistent with the monetary superpower hypothesis (Beckworth, 2012). Our paper thus also has some important implications for the years ahead as Central Bankers around the world are currently trying to "normalize" monetary policy. For the first time since the financial crisis of 2008, the Fed has been engaging on a path of timid but gradual interest rate increases. While the terminal endpoint is expected to be much lower than in the past, this monetary tightening will also affect many other economies. Our research suggests that the Eurozone will not be able to decouple itself from the US forever. One can thus expect European interest rates to eventually follow a similar path of that of the Fed and the same reasoning obviously also applies for smaller economies like Sweden. So much for monetary policy autonomy!

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Appendix

The appendix contains additional results and regression outputs that were omitted from the main body of the text. The first part of the appendix contains a summary of the assumptions and data adjustments we made in order to complete the data set. This is followed by additional tables and figures that support our model, but that we not included in the main part of the text.

We made the following assumptions and data adjustments to complete the time series data for each national interest rate from 1871 to 2013:

1) Belgium: We assume a constant nominal interest rate of 5% and subtract the rate of inflation for the years from 1915 to 1919.
2) Canada: Since there is no data available for the short-term rate real interest rate for the years from 1871 to 1933, we use the long-term real interest rate instead.
3) Denmark: We use the long-term real interest rate for the years from 1871 to 1874.
4) France: We use the long-term real interest rate for the years from 1915 to 1921.
5) Germany: We use the long-term real interest rate for the years from 1915 to 1919. For the year 1923, the actual real interest rate theoretically exceeds negative 10,000% during the year of the Weimar hyperinflation. We do not use that value and instead use the average of the preceding and subsequent year, which still yields a negative real interest rate of more than 230%. For the years from 1945 to 1947, we assume a constant nominal interest rate of 5% and subtract the rate of inflation. For the years 1948 and 1949, we use the long-term real interest rate instead.
6) Italy: We use the long-term real interest rate for the years from 1871 to 1884 and from 1915 to 1921.
7) Japan: We use the long-term real interest rate for the years from 1871 to 1878 and from 1939 to 1956.
8) Netherlands: We use the long-term real interest rate for the years from 1915 to 1918 and from 1945 to 1947.
9) Portugal: We use the long-term real interest rate for the years from 1871 to 1879.
10) Spain: We use the long-term real interest rate for the years from 1871 to 1882.

In the second part of the paper, we made the following assumptions concerning some of the large outliers in the data. We removed all negative interest rates in excess of minus 25%, corresponding to large inflationary episodes or even periods hyperinflations. We also removed all positive real interest rates in excess of 20%, corresponding to severe deflationary episodes. The reason for the assymetry is that high annual inflation rates and hyperinflations are more common whereas deflationary episodes rarely exceed more than 15%, even during the Great Depression. While those two thresholds are chosen somewhat arbitarily, changing them by a few percentage points in either direction does not seem to affect our results in any meaningful way. Moreove, the thresholds were chosen in such a way as to eliminate some of the largest outliers while at the same time conserving as much of the original data as possible. Since we need a complete data set, we have decided to replace all outliers with their upper and lower bound of 0.2 and −0.25, respectively.

1) Belgium: We use the value −0.25 for the years from 1915 to 1918 and from 1940 to 1942. We use 0.2 for the year 1919 and 1944.
2) Denmark: We use the value 0.2 for the years 1921, 1922, and 1926.
3) Finland: We use the value −0.25 for the years 1917, 1918, 1945, and 1946.
4) France: We use the value −0.25 for the year 1920 and from 1945 to 1948.
5) Germany: We use the value −0.25 for the years 1917, 1919, 1920 and from 1922 to 1924.
6) Italy: We use the value −0.25 for the years 1917, 1918 and from 1944 to 1948. We use the value 0.2 for the year 1875.
7) Japan: We use the value −0.25 for the years from 1944 to 1948. We use the value 0.2 for the years 1871, 1872, 1876, 1884, and 1886.
8) Norway: We use the value −0.25 for the years 1915 and 1917. We use the value 0.2 for the years 1922 and 1926.
9) Portugal: We use the value −0.25 for the years 1918, 1920, 1921, and 1923. We use the value 0.2 for the years 1874 and 1948.
10) Spain: We use the value −0.25 for the year 1918. We use the value 0.2 for the years from 1876 to 1878 and 1921.
11) Sweden: We use the value −0.25 for the year 1918. We use the value 0.2 for the years 1921 and 1922.
12) Switzerland: We use the value 0.2 for the years 1874 and 1922.

Table 1
Adoption of the gold standard by country.

Country	Adoption of the gold standard
AUS	1852
BEL	1878
CAN	1853
DK	1873
FIN	1877
FR	1887
GER	1872
ITA	1884
JP	1879
NL	1875
NOR	1873
PRT	1854
ESP	1913
SWE	1873
CHE	1878
UK	1816
US	1879

Source: Meissner (2005).

Table 2
Dickey-Fuller test for the short-run real interest rate, using two lags:
The null hypothesis that the real interest rate is a unit root can strongly be rejected for all countries.

Country	Test statistic
AUS	−3.64***
BEL	−6.29***
CAN	−4.87***
DK	−5.05***
FIN	−4.77***
FR	−3.16**
GER	−5.34***
ITA	−3.93***
JP	−4.74***
NL	−4.56***
NOR	−4.41***
PRT	−3.14**
ESP	−4.44***
SWE	−6.08***
CHE	−472***
UK	−4.39***
US	−4.78***

Source: Author's calculation.
Using two lags. we have 140 observations. The 1%, 5%, and 10% critical value are negative 3.5, 2.89, and 2.58, respectively.

Table 3
Cross-country correlations of the short-run real interest rate:

a) Entire sample, 1871–2013: Average cross-country correlation: 0.420

n = 143	AUS	BEL	CAN	DK	FIN	FR	GER	ITA	JP	NL	NOR	PRT	ESP	SWE	CHE	UK	US
AUS																	
BEL	0.273																
CAN	0.607	0.416															
DK	0.456	0.450	0.639														
FIN	0.335	0.470	0.463	0.422													
FR	0.515	0.278	0.603	0.375	0.500												
GER	−0.017	0.111	−0.083	−0.025	0.016	0.117											
ITA	0.234	0.157	0.338	0.242	0.408	0.537	0.027										
JP	0.270	−0.121	0.289	0.155	0.391	0.613	−0.034	0.497									
NL	0.485	0.423	0.685	0.754	0.501	0.556	−0.134	0.376	0.340								
NOR	0.475	0.609	0.560	0.763	0.609	0.324	−0.065	0.298	0.139	0.685							
PRT	0.174	0.270	0.196	0.279	0.447	0.257	0.474	0.262	0.119	0.269	0.296						
ESP	0.477	0.437	0.633	0.642	0.589	0.523	−0.047	0.388	0.294	0.673	0.628	0.346					
SWE	0.569	0.520	0.652	0.740	0.670	0.406	−0.210	0.246	0.175	0.705	0.800	0.253	0.728				
CHE	0.355	0.548	0.633	0.669	0.473	0.358	−0.147	0.307	0.100	0.678	0.669	0.304	0.618	0.728			
UK	0.639	0.551	0.751	0.752	0.616	0.590	−0.136	0.383	0.268	0.753	0.768	0.319	0.696	0.820	0.687		
US	0.569	0.376	0.759	0.566	0.517	0.639	0.007	0.402	0.358	0.577	0.546	0.298	0.712	0.630	0.563	0.723	

b) Classical gold standard, 1871–1913: Average cross-country correlation: 0.237

n = 43	AUS	BEL	CAN	DK	FIN	FR	GER	ITA	JP	NL	NOR	PRT	ESP	SWE	CHE	UK	US
AUS																	
BEL	0.309																
CAN	0.132	0.355															
DK	−0.170	0.267	0.424														
FIN	0.107	0.227	0.293	0.522													
FR	0.224	0.187	−0.021	0.023	0.009												
GER	−0.114	0.364	0.265	0.566	0.493	0.110											
ITA	−0.115	0.291	0.321	0.405	0.217	0.243	0.587										
JP	0.001	−0.092	−0.099	−0.045	−0.097	−0.119	−0.249	−0.275									
NL	−0.149	0.363	0.480	0.567	0.408	0.102	0.593	0.614	−0.180								
NOR	0.111	0.326	0.319	0.657	0.741	0.068	0.590	0.459	0.080	0.591							
PRT	−0.056	0.228	0.083	0.066	−0.078	−0.092	0.083	0.131	−0.016	0.165	0.130						
ESP	0.022	0.172	0.417	0.386	0.171	−0.105	0.274	0.333	−0.069	0.247	0.391	0.198					
SWE	0.098	0.347	0.277	0.572	0.791	−0.013	0.583	0.365	−0.067	0.474	0.870	0.229	0.374				
CHE	−0.132	0.484	0.479	0.477	0.316	0.200	0.552	0.530	−0.485	0.583	0.332	0.435	0.244	0.439			
UK	−0.071	0.436	0.445	0.437	0.407	0.131	0.569	0.428	−0.330	0.471	0.467	0.238	0.430	0.510	0.658		
US	0.193	−0.065	0.293	0.070	0.079	0.182	−0.007	0.224	0.089	0.115	0.207	−0.036	0.532	0.072	0.093	0.261	

c) Interwar period, 1914–1944: Average cross-country correlation: 0.501

n = 31	AUS	BEL	CAN	DK	FIN	FR	GER	ITA	JP	NL	NOR	PRT	ESP	SWE	CHE	UK	US
AUS																	

(continued on next page)

Table 3 (*continued*)

a) Entire sample, 1871–2013: Average cross-country correlation: 0.420

n = 143	AUS	BEL	CAN	DK	FIN	FR	GER	ITA	JP	NL	NOR	PRT	ESP	SWE	CHE	UK	US
BEL	0.371																
CAN	0.740	0.545															
DK	0.733	0.477	0.749														
FIN	0.331	0.552	0.465	0.420													
FR	0.617	0.422	0.767	0.542	0.304												
GER	−0.106	−0.030	−0.156	−0.120	−0.081	−0.011											
ITA	0.208	0.153	0.343	0.195	0.296	0.441	−0.082										
JP	0.602	0.160	0.648	0.597	0.524	0.553	−0.133	0.643									
NL	0.756	0.576	0.787	0.875	0.485	0.750	−0.275	0.296	0.603								
NOR	0.582	0.706	0.663	0.798	0.651	0.423	−0.163	0.274	0.449	0.747							
PRT	0.119	0.254	0.263	0.283	0.522	0.330	0.520	0.193	0.235	0.219	0.280						
ESP	0.640	0.606	0.739	0.756	0.676	0.627	−0.193	0.341	0.647	0.851	0.736	0.236					
SWE	0.703	0.581	0.764	0.800	0.738	0.551	−0.328	0.208	0.644	0.842	0.794	0.165	0.903				
CHE	0.713	0.706	0.820	0.809	0.606	0.624	−0.300	0.310	0.580	0.843	0.858	0.183	0.853	0.887			
UK	0.721	0.620	0.855	0.889	0.634	0.655	−0.303	0.326	0.686	0.897	0.871	0.262	0.828	0.904	0.909		
US	0.742	0.492	0.939	0.731	0.514	0.729	−0.083	0.349	0.660	0.757	0.669	0.337	0.737	0.772	0.812	0.837	

d) Bretton Woods, 1945–1973: Average cross-country correlation: 0.276

n = 29	AUS	BEL	CAN	DK	FIN	FR	GER	ITA	JP	NL	NOR	PRT	ESP	SWE	CHE	UK	US
AUS																	
BEL	0.155																
CAN	0.725	0.294															
DK	0.546	0.312	0.424														
FIN	0.297	−0.393	0.583	0.046													
FR	0.424	−0.295	0.742	0.056	0.904												
GER	0.120	0.239	0.566	0.056	0.439	0.571											
ITA	0.177	−0.618	0.307	0.022	0.666	0.676	0.176										
JP	0.181	−0.706	0.321	−0.055	0.725	0.748	0.243	0.919									
NL	0.383	−0.419	0.435	0.222	0.611	0.525	0.156	0.552	0.622								
NOR	0.568	0.213	0.227	0.445	−0.023	−0.084	−0.153	−0.075	−0.162	0.210							
PRT	−0.093	−0.590	−0.359	−0.115	0.052	−0.100	−0.156	0.234	0.181	0.286	0.010						
ESP	0.132	−0.138	0.463	0.181	0.679	0.592	0.284	0.471	0.343	0.466	0.027	0.192					
SWE	0.715	0.481	0.613	0.624	0.100	0.158	0.257	−0.008	−0.083	0.224	0.752	−0.253	0.132				
CHE	0.216	0.386	0.340	0.444	0.022	0.051	0.361	0.156	0.009	0.162	0.271	−0.104	0.160	0.569			
UK	0.842	0.128	0.784	0.390	0.434	0.594	0.303	0.296	0.307	0.418	0.477	−0.191	0.255	0.650	0.309		
US	0.490	−0.004	0.795	0.148	0.742	0.842	0.628	0.551	0.472	0.334	0.090	−0.047	0.654	0.376	0.212	0.635	

e) Floating exchange rates, 1974–2013: Average cross-country correlation: 0.665

n = 40	AUS	BEL	CAN	DK	FIN	FR	GER	ITA	JP	NL	NOR	PRT	ESP	SWE	CHE	UK	US
AUS																	
BEL	0.649																

(continued on next page)

Table 3 (*continued*)

a) Entire sample, 1871–2013: Average cross-country correlation: 0.420

n = 143	AUS	BEL	CAN	DK	FIN	FR	GER	ITA	JP	NL	NOR	PRT	ESP	SWE	CHE	UK	US
CAN	0.775	0.837															
DK	0.605	0.827	0.740														
FIN	0.858	0.759	0.797	0.719													
FR	0.768	0.693	0.803	0.798	0.773												
GER	0.649	0.868	0.797	0.799	0.686	0.829											
ITA	0.844	0.687	0.817	0.727	0.835	0.914	0.711										
JP	0.709	0.688	0.679	0.640	0.764	0.558	0.517	0.643									
NL	0.740	0.866	0.777	0.803	0.798	0.779	0.847	0.737	0.617								
NOR	0.733	0.694	0.704	0.747	0.847	0.779	0.668	0.751	0.685	0.757							
PRT	0.743	0.285	0.468	0.329	0.602	0.593	0.323	0.633	0.564	0.490	0.510						
ESP	0.831	0.683	0.730	0.727	0.813	0.815	0.687	0.842	0.690	0.816	0.722	0.724					
SWE	0.801	0.475	0.684	0.520	0.706	0.814	0.561	0.851	0.550	0.604	0.709	0.762	0.736				
CHE	0.478	0.244	0.460	0.266	0.506	0.516	0.252	0.497	0.243	0.338	0.520	0.567	0.431	0.487			
UK	0.830	0.711	0.796	0.628	0.860	0.771	0.741	0.788	0.588	0.799	0.769	0.625	0.822	0.763	0.461		
US	0.621	0.719	0.793	0.568	0.663	0.638	0.723	0.710	0.525	0.577	0.496	0.191	0.593	0.507	0.149	0.712	

Source: Author's calculation.

Table 4
Correlation between the first common factor and the global real interest rate

Correlation	1871–2013	1871–1913	1914–1944	1945–1973	1973–2013
	0.591	0.779	0.481	0.702	0.93

Source: Author's calculation.

Table 5
Summary statistics of the VECM.

a) Entire sample. 1871–2013:				
n = 141	Alpha 1	Lambda 1	Lambda 0	Half-life: ln(0.5)/(ln(1 + alpha)
AUS	−0.380***	−0.044***	−0.002	1.449
BEL	−0.596***	−0.077***	0.024**	0.765
CAN	−0.903***	−0.039***	−0.005*	0.297
DK	−1.120***	−0.041***	−0.015***	
FIN	−0.865***	−0.108***	0.036***	0.347
FR	−0.049	−0.172***	0.080***	13.733
GER	−0.030	−0.862***	0.369**	22.778
ITA	−0.402***	−0.135***	0.053**	1.347
JP	−0.330***	−0.199***	0.079**	1.730
NL	−1.003***	−0.041***	0.000	
NOR	−0.643***	−0.062***	−0.001	0.673
PRT	−0.162***	−0.193***	0.078**	3.934
ESP	0.095	−0.099***	0.022**	
SWE	−1.111***	−0.044***	−0.005**	
CHE	−0.976***	−0.035***	−0.002	0.185
UK	−0.048	−0.056***	0.010***	14.207
US	−0.491***	−0.042***	−0.003	1.025
b) Classical gold standard. 1871–1913:				
n = 41	Alpha 1	Lambda 1	Lambda 0	Half-life: ln(0.5)/(ln(1 + alpha)
AUS	−0.374***	−0.102***	0.053**	1.482
BEL	−1.392***	−0.038***	−0.005	
CAN	−0.576*	−0.067***	0.024***	0.807
DK	−0.157	−0.089***	0.025**	4.071
FIN	−1.150***	−0.036***	−0.016	
FR	−1.137***	0.002	−0.026***	
GER	−1.381***	−0.029***	−0.004	
ITA	−1.082***	−0.003	−0.044***	
JP	−0.728***	−0.071***	−0.002	0.533
NL	−1.464***	−0.041***	0.002	
NOR	−1.696***	−0.081***	0.020***	
PRT	−1.616***	−0.023*	−0.027**	
ESP	0.090	−0.239***	0.135***	
SWE	−0.812***	−0.009	−0.037***	0.414
CHE	−1.433***	−0.044***	−0.008	
UK	−1.464***	−0.012***	−0.017***	
US	0.045	−0.114***	0.053**	
c) Interwar period. 1914–1944:				
n = 31	Alpha 1	Lambda 1	Lambda 0	Half-life: ln(0.5)/(ln(1 + alpha)
AUS	−0.656**	−0.027***	0.053*	0.649
BEL	−0.651**	−0.096***	0.087***	0.658
CAN	−1.375***	−0.035***	−0.018***	
DK	−1.591***	−0.044***	−0.011**	
FIN	−1.129***	−0.112***	0.053**	
FR	−1.141***	−0.041***	0.064***	
GER	−0.003	−7.392**	0.900	267.267
ITA	0.003	−0.673***	0.146	
JP	−0.952***	−0.037***	−0.024	0.228
NL	−1.049**	−0.039***	−0.005	
NOR	−0.034	−0.071***	0.000	19.849
PRT	−0.012	−1.821***	0.232	56.503
ESP	−0.698	−0.053***	0.008	0.579
SWE	−1.117**	−0.051***	−0.009	
CHE	−1.156***	−0.036***	−0.001	

(*continued on next page*)

Table 5 (*continued*)

a) Entire sample. 1871–2013:				
n = 141	Alpha 1	Lambda 1	Lambda 0	Half-life: ln(0.5)/(ln(1 + alpha)
UK	−1.269	−0.047***	0.009***	
US	−1.433***	−0.034***	−0.008	
d) Bretton Woods. 1945–1973:				
n = 29	Alpha 1	Lambda 1	Lambda 0	Half-life: ln(0.5)/(ln(1 + alpha)
AUS	−0.116	−0.118***	0.003	5.603
BEL	−1.038***	0.028	−0.025***	
CAN	−0.037	−0.088***	−0.002	18.509
DK	−0.938***	−0.008	−0.018***	0.249
FIN	0.063	−0.367***	0.004	
FR	0.151**	−0.588***	0.046	
GER	−0.603***	0.019	−0.011	0.751
ITA	−0.611***	−0.057	0.002	0.735
JP	−0.205	−1.082***	0.068	3.019
NL	−0.552*	−0.059***	0.004	0.863
NOR	−0.613***	0.018	0.004	0.731
PRT	−1.222***	−0.020	0.003	
ESP	−0.551**	−0.034	0.029**	0.865
SWE	−0.985***	−0.009	−0.004	0.165
CHE	−0.772***	0.015	0.003	0.470
UK	0.528**	−0.089***	0.001	
US	0.163	−0.171***	−0.010	
e) Floating exchange rates. 1974–2013:				
n = 40	Alpha 1	Lambda 1	Lambda 0	Half-life: ln(0.5)/(ln(1 + alpha)
AUS	−0.615***	−0.051***	−0.008*	0.726
BEL	−0.063	−0.048***	−0.002	10.726
CAN	−0.355	−0.044***	−0.004*	1.580
DK	−0.164	−0.043***	−0.011*	3.881
FIN	−0.877***	−0.067***	0.008**	0.331
FR	−0.559***	−0.047***	0.000	0.847
GER	−0.489***	−0.030***	−0.005*	1.032
ITA	−0.318	−0.060***	0.003	1.811
JP	−0.505**	−0.035***	0.004	0.985
NL	−0.466**	−0.044***	0.001	1.106
NOR	−0.692***	−0.044***	−0.014***	0.588
PRT	−0.552***	−0.074***	0.042***	0.862
ESP	−0.894***	−0.076***	0.019***	0.309
SWE	−0.807***	−0.049***	0.001	0.421
CHE	−0.532***	−0.017**	0.005	0.914
UK	−0.718**	−0.064***	0.008	0.548
US	−0.296*	−0.035***	0.002	1.972

Source: Author's calculation.

Table 6
Panel-VAR estimation

		(1)	(2)	(3)	(4)	(5)
		1871–2013	1871–1913	1914–1944	1945–1973	1974–2013
		n = 1246	n = 191	n = 264	n = 287	n = 601
Δy	L1.Δy	0.397***	−0.309***	1.025***	0.011	0.304***
	L1.Δcpi	0.067***	0.162***	0.334***	−0.395***	−0.008
	L1.ir	−0.002***	0.000	0.001	−0.001	−0.003***
	L1.$\Delta stock$	0.042***	0.118***	−0.029	0.025**	0.030***
	L1.Δhp	−0.009	0.052***	−0.149***	0.007	0.015
	L1.Δc	−0.014	0.079***	−0.182***	0.248***	0.029*
	L1.iy	−0.197***	−0.115	−0.201***	0.015	−0.159**
	L1. cap share	−0.003***	–	−0.004***	−0.004***	−0.004***
	f_1	0.005*	−0.001	0.004	0.005	0.018***
	L1.f_1	−0.003	0.001	0.002	−0.015**	−0.009**
	f_2	0.002	0.007	−0.006*	0.011***	−0.007
	L1.f_2	0.003	−0.014**	0.011***	−0.007***	0.010*

(*continued on next page*)

Table 6 (*continued*)

		(1) 1871–2013 n = 1246	(2) 1871–1913 n = 191	(3) 1914–1944 n = 264	(4) 1945–1973 n = 287	(5) 1974–2013 n = 601
Δ*cpi*	L1.Δ*y*	−0.155***	0.058*	−0.890***	−0.100**	0.234***
	L1.Δ*cpi*	0.181***	0.370***	0.012	0.620***	0.495***
	L1.ir	0.005***	−0.001	−0.001	0.000	0.002***
	L1.Δ*stock*	0.034***	0.084***	0.115***	0.072***	0.010***
	L1.Δ*hp*	0.013	0.003	0.100***	0.039**	0.021*
	L1.Δ*c*	0.184***	0.096***	0.233***	0.055**	0.047***
	L1.iy	−0.022	−0.034	0.397***	−0.145*	0.019
	L1. cap share	0.000	–	0.005***	−0.002**	−0.002***
	f_1	−0.040***	−0.029***	−0.041***	−0.044***	−0.021***
	L1.f_1	0.007**	0.002	0.009**	0.030***	0.005
	f_2	−0.002	0.001	−0.003	−0.003	0.007*
	L1.f_2	0.001	−0.009*	−0.002	0.005	0.006
ir	L1.Δ*y*	6.238***	10.264***	−2.446***	11.597***	17.247***
	L1.Δ*cpi*	−2.182***	2.877**	−4.431***	15.108***	6.947
	L1.ir	0.869***	0.478***	0.910***	0.717***	0.719***
	L1.Δ*stock*	1.752***	4.259***	0.842***	3.859***	0.858***
	L1.Δ*hp*	0.454	−0.598	3.255***	−6.299***	1.707
	L1.Δ*c*	7.612***	1.141	3.820***	9.814***	9.703***
	L1.iy	−7.749***	2.583	−5.398***	−1.557	−16.445**
	L1. cap share	−0.057*	–	−0.050***	−0.054**	−0.153**
	f_1	0.362***	−0.184	−0.028	0.780***	1.335***
	L1.f_1	−0.384***	0.084	−0.141***	0.402***	−0.959***
	f_2	0.223***	−0.268	0.040	−0.203**	2.083***
	L1.f_2	0.014	0.278	−0.002	0.253***	−0.643
Δ*stock*	L1.Δ*y*	−0.197	−0.984***	0.694***	−3.862***	0.539
	L1.Δ*cpi*	−1.267***	−0.019	−0.462***	−3.677***	0.205
	L1.ir	0.007**	−0.011*	0.011***	0.014***	−0.019***
	L1.Δ*stock*	0.283***	0.175***	0.293***	0.049	0.138***
	L1.Δ*hp*	−0.463***	0.057	−0.016	0.207***	−0.293**
	L1.Δ*c*	0.342***	−0.417***	−0.277***	0.865***	0.067
	L1.iy	−0.678***	0.469	0.108	−0.681*	−2.086***
	L1. cap share	−0.013***	–	−0.005***	−0.015***	−0.033***
	f_1	0.001	−0.026	−0.011*	0.014	0.133***
	L1.f_1	−0.063***	−0.018	−0.022***	−0.186***	−0.025
	f_2	−0.014	0.013	−0.013*	−0.019	0.293***
	L1.f_2	0.026**	−0.051**	0.033***	0.046***	−0.169***
Δ*hp*	L1.Δ*y*	−0.089	0.125	−0.249***	−0.412**	0.254
	L1.Δ*cpi*	−0.048	0.523***	−0.080**	−0.046	0.463
	L1.ir	−0.003**	−0.004	0.005**	0.005*	−0.013***
	L1.Δ*stock*	0.087***	0.237***	0.146***	0.011	0.006
	L1.Δ*hp*	0.232***	−0.142**	0.327***	0.094*	0.281***
	L1.Δ*c*	0.362***	0.178***	0.090**	0.755***	0.676***
	L1.iy	−0.149	−0.054	−0.021	0.936***	−0.700**
	L1. cap share	−0.005***	–	−0.003***	0.000	−0.011***
	f_1	−0.005	−0.030**	−0.008**	0.005	0.013
	L1.f_1	−0.004	0.012	−0.004	−0.004	0.022
	f_2	−0.008	−0.017	−0.011**	−0.051***	0.045
	L1.f_2	0.009*	−0.026	0.000	0.029***	−0.032
Δ*c*	L1.Δ*y*	0.467***	0.144**	0.627***	−0.535***	0.468***
	L1.Δ*cpi*	0.148***	0.102	0.156***	−0.844***	0.592***
	L1.ir	0.000	−0.010**	0.014***	−0.001	−0.008***
	L1.Δ*stock*	0.059***	0.089***	0.094***	0.014	0.017*
	L1.Δ*hp*	0.050	0.094***	0.101***	0.188***	0.069**
	L1.Δ*c*	0.456***	0.189***	0.374***	0.753***	0.683***
	L1.iy	−0.130	0.134	−0.286***	−0.544***	−0.145
	L1. cap share	−0.004***	–	−0.003***	−0.011***	−0.006***
	f_1	−0.003	−0.027***	−0.008**	−0.014	0.021**
	L1.f_1	−0.008*	−0.004	−0.008*	−0.027**	0.006
	f_2	0.002	−0.019	0.002	0.007	0.003
	L1.f_2	0.004	0.018	0.014***	0.000	0.010
iy	L1.Δ*y*	0.123***	0.028	0.237***	0.003	0.136***
	L1.Δ*cpi*	0.010	0.098***	0.079***	−0.166***	0.238***
	L1.ir	−0.001***	−0.003***	0.001**	0.000	−0.003***
	L1.Δ*stock*	0.027***	0.027**	0.043	0.013***	0.009***
	L1.Δ*hp*	0.005	−0.005	−0.011	0.029***	0.007
	L1.Δ*c*	0.000	0.024	−0.023	0.075***	0.066***
	L1.iy	0.956***	0.880***	0.782***	0.830***	0.730***

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Table 6 (*continued*)

		(1) 1871–2013 n = 1246	(2) 1871–1913 n = 191	(3) 1914–1944 n = 264	(4) 1945–1973 n = 287	(5) 1974–2013 n = 601
	L1. cap share	0.000	–	−0.002***	−0.001**	0.000
	f_1	−0.001	−0.004	0.000	−0.003*	0.004**
	L1.f_1	0.003**	−0.002	0.001	−0.001	0.006***
	f_2	0.000	0.004	0.004***	0.005***	−0.001
	L1.f_2	−0.001	−0.010***	0.001	−0.007***	0.003
cap share	L1.Δ*y*	9.625***	–	45.922***	−18.434***	1.932
	L1.Δ*cpi*	−4.505***	–	13.147***	−21.365***	−3.209
	L1.ir	−0.013	–	0.429***	0.179***	−0.114
	L1.Δ*stock*	0.830***	–	−4.407***	2.592***	1.172***
	L1.Δ*hp*	−2.080***	–	−4.317***	−3.978***	0.736
	L1.Δ*c*	−4.266***	–	−9.624***	4.242***	−9.967***
	L1.iy	−11.371***	–	−19.609***	−1.991	−0.431
	L1. cap share	0.786***	–	0.775***	0.881***	0.692***
	f_1	−0.288**	–	−0.487***	−0.107	0.377
	L1.f_1	0.156	–	0.679***	−0.541***	−0.183
	f_2	0.206*	–	−0.178	0.368***	0.077
	L1.f_2	0.051	–	0.675***	−0.335***	0.937**

Source: Author's calculation.

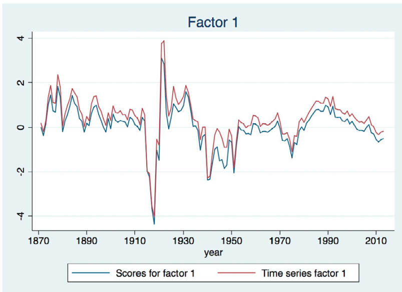

Fig. 1. Static factor model vs. TSFA for the first common factor

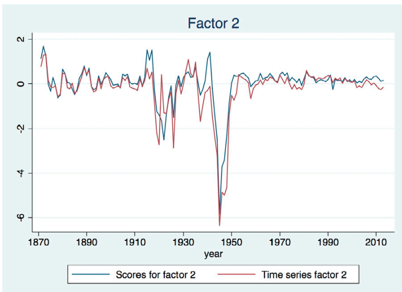

Fig. 2. Static factor model vs. TSFA for the second common factor

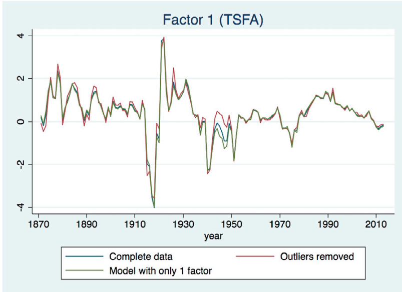

Fig. 3. TSFA for the first common factor, based on different assumptions

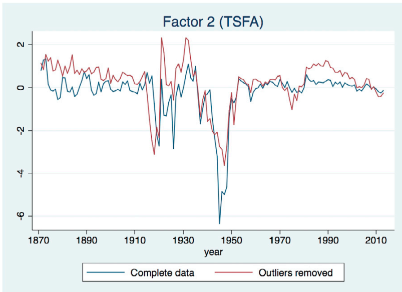

Fig. 4. TSFA for the second common factor, based on different assumptions

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Paper IV

ABSTRACT

We estimate Zipf's law for all Swedish cities from 1810 to 2010. We can reject the power law for the early 19th century when market integration was still low and urbanisation had not even reached 10%. In terms of the Zipf's law coefficient, we find that it rises from unity to an absolute high of 1.3 during the period of industrialisation, thus indicating a tendency towards greater population concentration. Surprisingly, the coefficient falls over the course of the 20th century, thus indicating a trend in the opposite direction. The Swedish city network is characterized by the dominance of Stockholm as the primate city with a population level above its Zipf-consistent. Meanwhile many other cities in the upper part of the city size distribution have population levels well-below their Zipf-consistent estimate. Using a nonparametric estimator, we show that Gibrat's law is violated in the Swedish case throughout most time periods. We find a negative relationship between city rank and city growth rates for the 19th century. The relationship reverses for the 20th century. Somewhat surprisingly, Sweden is a case where the large cities have consistently grown below average in recent decades, thus explaining why their actual population is below the Zipf-consistent estimates.

Key words:
Urban hierarchy, Zipf's law, Gibrat's law, random growth theory, agglomeration effects

Zipf's law for Swedish cities from 1810 to 2010

1. Introduction

It has always been clear that a large fraction of economic activity is geographically highly concentrated in economic clusters, also known as cities. Moreover, increasing urbanisation around the world has meant that these clusters have been gaining in importance in recent decades even as globalisation proceeded at a more rapid pace (Leamer, 2007). A study by the McKinsey Global Institute shows that the top 600 urban centres account for about 60 percent of global GDP in 2010, generated by about a fifth of the global population. Moreover, the top 100 cities will contribute about 35 percent of global growth in between 2010 and 2025 (Dobbs et al., 2011). While most of the recent surge in global urbanisation is due to the rise of large metropolitan areas in South East Asia, economic activity also seems to become even more concentrated in advanced economies like the United States (US) where just a handful of the large metropolitan areas have generated the majority of economic growth in recent years (Moretti, 2012). This phenomenon is occurring despite the fact that urbanisation rates in advanced economies were already quite high by the middle of the 20th century (Brezzi et al., 2012).

In the case of Sweden, one can also observe a clear tendency towards increasing agglomerations over the last century. The Swedish economy is divided into 21 counties with Stockholm län (county) being one of the smallest regions in terms of geographic size. The county comprises the country's capital city and had a total population share and GDP share of 10% and 13% in 1900, respectively, whereas in 2010 it already accounted for more than 22% of Sweden's population and 30% of national GDP (Enflo, 2014). The inhabitants of Stockholm län are thus more productive than the average Swede, pointing towards a correlation between population density and productivity, a relationship that has been established for many countries and time periods (Bairoch, 1991; Chen et al., 2014). However, our analysis shows that a simple narrative of increasing agglomeration forces risks oversimplifying the population dynamics that actually took place in Sweden over the last two centuries.

Sweden was a relative latecomer to the Industrial Revolution, which reached the country only by the end of the 19th century. The nation can be characterised as a frontier economy at the European periphery during the late 19th century (Schön, 2010). The strong economic expansion of the Northern part of the country was based on the exploitation of natural resources, such as mining and the forest and pulp industry. Sweden was still relatively poor and overwhelmingly rural in the first half of the 19th century, even though the population grew at double-digit rates on a decennial basis. A Swedish particularity is that the Industrial Revolution was not only urban in nature, but also reached the more rural areas. The urbanisation rate was only at 9% in 1810 and increased to just 13% by 1870 while today's value is slightly above 85% (van der Woude et al., 1995). Sweden is also quite unique in that more than a third of its cities ("localities") today did not exist as such 200 years ago.

Given the importance of cities for modern economic growth, many studies have analysed the city network and how it evolved over time during periods of rapid economic change (Bairoch, 1991). De Vries (2006), for example, provides an extensive overview of European urbanisation in the context of economic development for the pre-industrial period from 1500 to 1800. The urban hierarchy is often of particular interest because it describes the distribution of city sizes within a particular region or country. Urban economists have identified a long time ago that the city size distribution can be described by a power law and that the coefficient of this particular rank-size rule is magically close to one in most cases. Ranking all cities by population size, the nth city in the urban network therefore commonly has a population of 1/n that of the largest. Thus, the second largest city has a population of one half that of the largest, the third largest city that of one third, etc. This phenomenon, commonly called Zipf's law, is an empirical regularity that seems to describe city sizes reasonably well for many countries around the world (Gabaix, 1999a).

While most studies have documented Zipf's law in a more contemporaneous setting, such as Venables (2005), there have been very few attempts to estimate the relationship across several centuries, Dittmar (2011) and (Gonazalez-Val, 2017) being the notable exception. While their studies have analysed the European urban system during the early modern period, our paper contributes to the literature by providing a more detailed account of the power law on a more regional level for a time period of two centuries.

The aim of this paper is to provide an extensive analysis of the Swedish urban hierarchy from the early 19th century until today. We hope to gain additional insights on the nature of the rank-size rule in Sweden across two centuries of economic development. Furthermore, we also want to examine the relationship between city size and subsequent population growth rates. We focus on Sweden as a case study because of her rather atypical economic geography, being an extremely sparsely populated country at Europe's Northern periphery. The geographic distance between Swedish cities is therefore relatively large compared to continental Europe. With the exception of Greater Stockholm and Greater Gothenburg, Sweden has barely any cases where cities have merged into one larger unit, as it has been the case for many other European agglomerations. We do not expect Zipf's law to hold precisely in the Swedish case, especially during the entire time frame of 200 years of data that we consider in our study. In fact, it is well-known that the rank-size rule breaks down below a certain population threshold (Reed, 2002), which is extremely relevant in our case, given that most Swedish cities did not exceed more than a few hundred to a couple of thousand inhabitants before the Industrial Revolution. We therefore take an agnostic stance on the exact size of the power law coefficient. In fact, as Gabaix (1999a) has suggested, a coefficient in the range of 0.8 and 1.2 might be a reasonable approximation. We also do not expect the Zipf's law coefficient to be an immutable universal law like gravity, but rather a highly context-specific economic force that will depend on the institutional context and the socio-economic environment as well as the underlying forces of economic geography. Especially during times of rapid economic development, such as the Industrial Revolution, we expect that some fundamental changes will occur that can affect the rank-size relationship and thereby alter the city size distribution within the urban network.

The abundancy of Swedish population data allows us to estimate the rank-size rule in 10-year intervals from 1810 to 2010. While city population data is also available for the early modern period for contemporaneous Sweden, frequent territorial changes will probably obscure the Zipf's law analysis for that time period. More recent research supports the notion that the rank-size rule is ultimately related to market integration (Dittmar, 2011), meaning that one should account for the frequent territorial changes that took place during that time. In fact, the Southern part of Sweden, the region of Skaneland, previously belonged to the Kingdom of Denmark until they had to cease the territories in 1658 under the treaty of Roskilde. Frequent warfare and territorial disputes with Denmark during the 15th and 16th century thus presented an obstacle to migration, labour mobility, regional market integration, and thus also city growth. These factors, in turn, seem to have prevented the emergence of the power law for the Swedish city network until the country became unified in the late 1600s. While the population data for Swedish cities within the current boundaries of the country is very reliable, the same cannot be said for cities around the Baltic Sea that belonged to the Kingdom of Sweden during the Age of Empire when the country pushed for military expansion across Northern Europe. Swedish overseas territories included at times Finland, the Baltics, Northern Poland, and parts of Northern Germany. While any Zipf's law analysis should incorporate the aforementioned occupied territories, for data availability reasons we focus exclusively on cities that are now in contemporaneous Sweden. We therefore choose to start our analysis in 1810 only, after which date Swedish geographic boundaries did not change anymore. While Norway was technically in a political union with Sweden from 1814 until 1905, the two countries functioned mostly as separate economic entities.

Even though some studies, such as Gonzalez-Val (2016), analyse Zipf's law in early modern Europe, his sample only contains less than 20 Swedish cities for the entire period. However, the richness of historical Swedish population data allows us to start with an increased sample size of 92 cities in 1810 that continuously increases and reaches a sample size of 160 cities as of 2010. In terms of the Zipf's law analysis, our results show that the Zipf's law coefficient has been relatively steady in the early 19th century with values relatively close to the magical number of one. While for most decades for the time period under consideration we can confirm Gabaix's (1999a) assertion that the coefficient belongs to the subset of values ranging from 0.8 to 1.2, there are some notable exceptions. Our findings show that the Zipf's law coefficient increases markedly during the period of Industrialisation, thus pointing towards increasing population concentration within the city network. The Transportation Revolution must therefore have contributed to some fundamental changes in terms of economic geography between economic locations at the time. Somewhat surprisingly, the coefficient decreases by the end of the 20th century, therefore indicating a higher degree of population dispersion within the urban hierarchy. This can be explained by higher population growth at the lower end of the city size distribution, as a number of small towns have been added to the urban network throughout the last century.

We also use a more elaborate test suggested by Gabaix (1999a) and applied by Dittmar (2011) to analyse the power law in early modern Europe. Similar to Dittmar (2011), we can reject the power law for the first decades of the 19th century in the case of Sweden. This is ultimately not very surprising, given that the country was still quite underdeveloped at the time, with an urbanisation rate below 10%. Furthermore, being a sparsely settled region at Europe's Northern periphery, the degree of market integration within Sweden was relatively low as well. However, by the mid-19th century, the Gabaix test suggests that the urban hierarchy started to obey the power law distribution during the Swedish Industrialisation.

While random growth theory suggests that initial population size and subsequent population growth should be independent of each other, sometimes known as Gibrat's law (Klein and Leunig, 2015), we find some evidence against this proposition in the Swedish case throughout the two hundred years of data under consideration. Using a nonparametric estimator, we detect a slightly negative relationship between mean city growth and city rank for the pre-industrial period and for the time of the Industrial Revolution. Subsequently, this relationship is reversed and throughout the entire 20th century we find that mean population growth rates increase with city rank, especially in recent decades, meaning that small cities have been growing at a faster rate. Finally, we estimate Zipf-consistent population values for all cities in the urban hierarchy and find that the largest cities in Sweden, with the notable exception of Stockholm, are consistently smaller than implied by the benchmark. This result holds over the entire two centuries under consideration and could potentially have implications for long-run economic growth, given that a large body of academic literature confirms a positive relationship between productivity and city size (Glaeser et al., 2016).

2. Literature review

Economists have long understood the various benefits that arise from economic concentration and deep markets. Adam Smith (1796) points out that a larger market leads to an increase in the specialization of labor and thus a more efficient allocation of resources. Marshall (1890) discusses the importance of externalities for the localization of firms. Myrdal (1957) foresees that increasing returns to scale will play a crucial role in explaining agglomeration effects. It is not until the 1990s, however, that economists were able to formalize these ideas with more rigorous mathematical models, mostly based on the ideas of Krugman who can be seen as the founding father of the subfield of new economic geography (Krugman, 2008). It is thus only more recently that economists have started to analyse the geography of economic activity, and more specifically, the relative importance of first-nature vs.

second-nature geography as a determinant for city location. There is a long-standing debate whether geographic or economic fundamentals matter more for the spatial distribution of economic activity (Krugman, 1993a). Crafts (2011), for example, examines the relative importance of factor endowments vs. market access in determining industrial locations in the US during the second Industrial Revolution. His findings suggest that the role of factor endowments diminishes over time and that market access has gained in importance. Similarly, Wolf (2007) suggests that both factor endowments and market access played a role in determining the spatial distribution of industrial activity after Poland's reunification after World War I. More recently, Bosker and Boringh (2015) calculate the urban potential for a large number of European cities from 800 to 1800. Their findings indicate that first-nature geography played a crucial role for the initial determination of city location, but that the relative importance of market access has increased over time. This result is line with Moretti (2012) who shows that there is increasing economic concentration in the US. A few major technology hubs have gained in importance at the expense of the rest country while many small to medium-sized towns have stagnated in recent decades.

While the geographical distribution of economic clusters is certainly of interest, many researchers have studied the rank-size rule in order to get a better understanding of the population distribution within the urban hierarchy. Urban economists have found that the city size distribution tends to follow a specific power law where the exponent is usually equal or extremely close to one (Krugman, 1996). It is important to note though that the geographic unit of analysis plays an important role here. Venables (2005), for example, shows that Zipf's law holds for the US, but not for the European Union (EU). On the other hand, it seems to hold for many countries within the EU, but not necessarily for individual states within the US. (Cristelli et al., 2012). Giesen and Südekum (2010) find that Zipf's law holds both for Germany as a whole and for various subregions within Germany. Zipf's law can also be applied to different geographic units, such as municipalities instead of cities, for example (Morudu and Plessis, 2013).

Various explanations have been offered to explain the rank-size rule. A random growth model, for example, ultimately leads to a distribution that follows such a power law. In this particular case, city growth and city size should be independent of each other as suggested by Gibrat's law (Gabaix, 1999b). While the proposition put forward by Gabaix that city growth follows a stochastic growth process might hold in many instances, it is not entirely satisfactory since it suggests that geography does not play a crucial role in the determination of where economic activity is concentrated and how it develops over time. Krugman (1996), on the other hand, presents a model where the random distribution of first-nature geography produces a city rank-size distribution in accordance with Zipf's law. Naturally, the idea that geography instead of a simple random growth process drives urban development is more appealing. In fact, there is growing evidence that both first-nature geography and second-nature geography play an important role in the formation and spatial distribution of urban centres. However, it seems that second-nature geography, access to consumer markets, has become increasingly dominant in determining the geographic distribution of economic activities in recent centuries and decades (Bosker and Buringh, 2015). Black and Henderson (2003) examine the rank-size rule for the US over the 20th century. Their findings suggest that the emergence of the service economy has led to increasing concentration in the upper part of the city size distribution. Eeckhout (2004) confirms Zipf's law for all US cities above a certain size. He also finds that growth rates are proportionate in the long-run, meaning that Gibrat's law holds as well. However, other studies have rejected the strict interpretation of Zipf's law, meaning that the coefficient does not exactly assume the supposed value of one. Nitsch (2005), for example, has conducted a meta-analysis of estimated Zipf's law coefficients and finds that in most cases cities are more evenly distributed than suggested by the rank-size rule. Similarly, Soo (2005) uses the regular OLS estimator as well as the Hill estimator and rejects Zipf's law for the majority of cases in his sample of more than 70 countries. Regardless, Gabaix's (1999a) assertion that the Zipf's law coefficient usually belongs to the interval from 0.8 to 1.2 seems to hold for most countries and most time periods.

While most studies have analysed Zipf's law with more contemporaneous data, more recently some economic historians have started to analyse the city network in a more historical setting, especially for early modern Europe. Leunig and Klein (2015) study Gibrat's law in the UK during the Industrial Revolution. The authors show that the time period under consideration was revolutionary enough to violate the random growth model. More specifically, larger towns grew disproportionally faster during the end of the 18th and part of the 19th century. Dittmar (2011), and more recently Gonzalez-Val (2016), examine Zipf's law in the early modern period in Europe. Dittmar (2011) finds that the power law can be rejected until 1500 in Western Europe and even until 1800 in Eastern Europe. Typically, European cities were much smaller than implied by the benchmark in the early modern period. Dittmar (2011) shows that Zipf's law starts to hold as soon as goods and labor markets became more integrated, which happened much earlier in Western Europe than in the Eastern part of the continent. Serfdom as an institution was extremely prevalent in Eastern Europe and prevented those market forces from emerging by severely restricting labor mobility. Gonzalez-Val (2016) rejects the power law for Europe until 1700. Additionally, the author also finds that a plausible alternative model for the city size distribution in early modern Europe is a log-normal distribution. While Lilja (2011) has estimated the rank-size rule for historical Sweden and Finland in the late 16th and 17th century, his data is restricted to just three different data points in time. While our analysis only includes the geographic boundaries of contemporaneous Sweden, we have produced estimations for every single decade from 1810 to 2010.

3. Historical context

Sweden was a relatively poor and overwhelmingly rural economy at Europe's periphery in the early modern period. While Denmark, Sweden, and Norway legally were seperate souvereign states, the countries were actually joined by a single monarch and formed the Kalmar Union in 1397. The aim of this political union was to counter the influence the Hanseatic league in Northern Europe, but it was ultimately dissolved when Sweden rebelled and became independent in 1523 (Kent, 2008). While our city population database covers the current geographic territory of Sweden, one should bear in mind that Skaneland, a large region in the Southern part of the country, actually belonged to Denmark from the 12th century until the treaty of Roskilde in 1658. The town of Visby and the island of Gotland also belonged to Denmark and were ceased to Sweden already in 1645 (Kent, 2008).

The 17th century saw frequent warfare between Denmark and Sweden with some conflicts lasting up to several decades, most of them being territorial disputes about Skaneland, a region that nowadays comprises the Swedish provinces of Blekinge, Halland, and Scania. It is clear that these long-lasting military disputes had a significant impact on the city network by disrupting trade, market integration, and population growth. Some of the large cities in the sample, such as Malmö and Kalmar, thus belonged to the kingdom of Denmark and only became Swedish in 1658 when Denmark had to cease Skaneland as well as Norway. Sweden's most Southern povinces were thus only integrated into Sweden by the middle of the 17th century (Kent, 2008).

The subsequent period, also known as the Age of the Empire, was characterized by a prolonged period of imperial expansion with Sweden occupying vast territories around the Baltic Sea, ranging from Finland to the

Baltic states and even regions in Northern Germany around 1700 (Heckscher, 1954). While it would therefore also be an interesting case study to examine the distribution of city sizes around the entire Baltic Area during the time of Swedish expansion, population data for the towns around the Baltics is not as readily available as for the cities that lie within the current geographic boundaries of Sweden. As mentioned above, we therefore restrict our analysis to the period from 1810 onwards even though Swedish city population data is also available in 40-year intervals from 1570 onwards[1].

One should note that Sweden remained an extremely rural economy until the end of the 19th century. Even by 1800, the urbanisation rate was less than 10%. Per capita income was also much lower at the time, less than half of the industrial leader Great Britain (Maddison, 2007) The agricultural sector was the largest part of the economy with more than three quarters of the population employed in the sector (Schön, 2007). Sweden was a relative latecomer to the Industrial Revolution. Economic growth took off after 1870 and was higher in the decades thereafter than in many other Western European economies. This was partly a story of catch-up growth as the Swedish economy finally managed its transition from a mostly rural economy to a modern economy based on manufacturing. The end of the 19th century is thus the period of strong economic convergence during which the country caught up to other European nations in terms of per capita income (Schön, 2010). Some authors have argued that the financial revolution of the mid-19th century played a substantial part in this story of modernisation (Ögren, 2009). Deposit growth and growth in the broad money supply accelerated substantially after 1830. This increase in liquidity as well as large inflows of foreign capital were the basis of industrialisation and high economic growth in the second half of the 19th century. Ögren (2009) argues that financialisation was therefore a prerequisite to the structural transformation that changed Sweden from a largely agrarian economy into a modern industrialised nation within just a few decades after 1870. The construction of the railroad during the latter part of the 19th century helped to develop rural areas that were previously disconnected from the larger

[1] In a previous version of this paper, we also estimated the Zipf's law coefficient for Swedish cities from 1570 to 1800 in 40-year intervals. However, frequent territorial changes as a result of warfare during the early modern period make such an analysis challenging. Given that Zipf's law is ultimately related to market integration, the analysis would have to take the territorial changes into account. However, city population data for Swedish territories outside the current georgaphic boundaries is of much poorer quality. We have therefore decided to start the analysis by 1810 after which no significant border changes have taken place.

agglomerations (Berger and Enflo, 2015). It is noteworthy that Swedish industrialisation during the 19th century was quite rural in nature and also took place in small cities that became regional industrial centres in sparsely populated parts of the country. An important characteristic of Swedish industrialisation though is that the country's urbanisation rate started to increase only relatively late, by the end of the 19th century, after the Industrial Revolution had already reached Scandinavia. While Sweden's population growth rate quickly accelerated after 1800, its urbanisation rate only started to rise by the end of the century. The introduction of the potato seems to have played a quite significant role for Swedish population growth in the early 19th century (Berger, 2016), as it led to large increases in agricultural output and thus pushed the Swedish economy out of the Malthusian equilibrium when a substantial fraction of the population still lived at subsistence level. Population growth averaged out at a little less than 10% per decade in between 1820 and 1880. Sweden’s population therefore increased from about 2.3 million in 1800 to 5.1 million in 1900, and to about 9.4 million in 2010.

4. Data

We use two different data sources for this paper to obtain population levels for all Swedish cities using the current political boundaries of the country. We use the Folknet database from Umea University to get population data for all Swedish cities on a decennial basis from 1810 to 1990. We also supplement the data with statistics from the Swedish Statistics Office SCB for the decades 2000 and 2010 and add a number of localities to the dataset that never obtained the status of city based on the legal definition. However, as argued below, these localities include places like Lomma, which can be classified as cities today based on the definition of localities. While the Sweidish statistics office defines a locality as being any settlement above 200 inhabitants, meaning that the country consists of almost 2,000 units as of 2017, we have decided to adopt a population threshold for the modern period and only include the settlements with a population of more than 10,000 inhabitants as of 2010. We therefore obtain a dataset that comprises city population data for all cities in contemporaneous Sweden for 20 decades in total from 1810 to 2010. The number of cities in our sample almost doubles from 92 to 160 over the time period under consideration. While the Baltic Town database also comprises city data for all Swedish cities using the current geographic boundaries of the country from 1570 to 1800 in 40-year intervals, we have decided against incorporating this data into our analysis for the considerations mentioned above. Most importantly, frequent territorial changes during the early modern period would obscure the analysis, given that the rank-size rule is closely related to market integration.

5. Urban definition and other considerations

An urban area is by definition densely populated and also exceeds a certain population size (Ploeckl, 2016). However, this rather vague definition only raises the question of how densely populated the area must be and how high the population threshold should be for a human settlement to constitute a city. Surely, the definition must depend on country-specific characteristics as well as the time period under consideration. For early modern Europe, Bairoch et al. (1988) and De Vries (1984) use population thresholds of 5,000 and 10,000, respectively. However, in the case of Sweden this would eliminate basically all urban areas with the exception of Stockholm, Gothenburg, and Malmö before the 19th century, given that the average city size had only reached some 2,400 inhabitants by 1810. For the German region of Saxony, Ploeckl (2016) uses a more elaborate test where he also incorporates population density as well as the share of non-agricultural population and occupational structure to determine whether a settlement constitutes a city or not. This more elaborate test then leads to a moving population threshold over time. While such an approach seems to be more sensible than just using a simple static threshold, especially when considering a longer time period, we have decided to not pursue this path because of Sweden's rather unique economic history.

Enflo and López-Cermeño (2017) discuss in great detail how the Swedish Crown planted some 31 new towns during the period from 1570 to 1810. These "planted towns" as opposed to more "organic towns" were the result of deliberate planning where the Crown granted township rights to what were previously rural parishes. As argued by Heckscher (1954), the privileges of township were thus conferred to many communities that did not necessarily have any potential for urban development. In fact, Karlskrona was the only one of such planted towns that eventually exceeded the aforementioned population threshold of 5,000 inhabitants (Enflo and López-Cermeño, 2017). Even though many of these planted towns just had a few hundred to a couple of thousand inhabitants during the early modern period, they were effectively towns with all the privileges that the Crown had bestowed upon them, even though they were not really any larger than many other rural parishes in terms of population size. However, the Transport Revolution that occurred throughout the 19th century meant that many of these planted towns would eventually start growing organically after all (Enflo and López-Cermeño, 2017).

Given the considerations just mentioned above, we have decided against using any kind of population threshold in our study for the pre-industrial period as to not exclude these planted towns. Instead, the Folknet database uses the legal definition of a city, granted by royal charter. Based on the data by SCB, we have also added a number of "tatört" (localities) to the dataset from 1960 onwards, which have become urban centres in recent decades but never had obtained any town privileges by the crown during historic times. Consequently, the number of Swedish cities in our data increases from a mere 92 in 1810 to 160 in 2010 in our sample.

Table 1 below displays some descriptive statistics. Sweden was a very poor, sparsely inhabited and overwhelmingly rural economy at Europe's periphery in the 16th century. Most cities merely had a few hundred to a few thousand inhabitants at that time. The average city population increased from less than 2,500 in 1810 to more than 10,000 by 1900, and about 36,000 by 2010. Urbanisation started to increase rapidly during the 19th century with average city population growth rates in the double digits, starting from well-below 10% in 1800. The total urban population in our data starts from less than 230.000 in 1810 and increases to about 5.8 million in 2010. Table 1 also shows that city growth was relatively high again during the end of the 20th century.

One of the questions that must be addressed, especially with regards to the larger agglomerations, thus concerns the administrative boundaries of the city. While Stockholm municipality only has about 940,000 inhabitants as of 2017, the metropolitan area of Stockholm now comprises almost 2.3 million people. However, for the purpose of our analysis, we do not take the entire population of the metropolitan area into account. We restrict our attention to the population data of what the Swedish statistics office has defined as "urban areas" (localities) instead. As such, the urban area of Stockholm had about

Table 1:
Descriptive statistics for Swedish cities

Time	Sample size	Mean	Max	Min	Std. dev.	Avg. Growth rate	Std. dev.	Urban population
1810	92	2,487	65,474	221	6,978	16.1%	14.6%	228,804
1820	94	2,768	75,569	109	7,962	13.4%	14.4%	260,192
1830	95	3,036	80,621	75	8,522	13.8%	24.2%	288,420
1840	95	3,280	84,161	238	8,921	11.6%	24%	311,600
1850	96	3,752	93,070	426	9,932	15.2%	15.8%	360,192
1860	100	4,489	112,391	347	11,916	21.8%	19.6%	448,900
1870	101	5,508	136,016	453	14,755	18%	17.2%	556,308
1880	101	7,065	168,775	432	18,621	26.8%	28%	713,565
1890	102	9,096	246,454	552	26,648	21.5%	32.7%	927,792
1900	106	10,896	300,624	568	32,040	25.5%	27.8%	1,154,976
1910	118	12,442	342,323	639	35,632	29%	38%	1,468,156
1920	126	14,753	419,429	709	42,687	28.8%	39.8%	1,858,878
1930	129	16,556	502,207	600	50,368	11.8%	18.2%	2,135,724
1940	142	19,229	590,543	596	58,662	14.7%	14.1%	2,730,518
1950	155	23,690	814,850	388	75,735	39.4%	63.4%	3,671,950
1960	155	25,703	957,655	479	86,294	38%	53.1%	3,983,965
1970	159	29,635	973,392	1,170	88,449	51.2%	89.3%	4,711,965
1980	159	29,579	989,424	1,319	87,831	15.5%	53%	4,703,061
1990	160	30,327	1,040,907	517	91,396	5.9%	17.8%	4,852,320
2000	160	33,651	1,212,179	1,377	104,779	19%	102%	5,384,160
2010	160	36,728	1,372,565	1,319	118,320	6.3%	11.5%	5,876,480

Source: CyberCity, Folknet database, SCB, author's calculations

1.37 million inhabitants as of 2010. Part of this can be attributed to the growth of agglomerations. For example, Nacka and Södertälje were treated in the sample before 1950 as being independent cities in close proximity to Stockholm. After that date, both localities have been included into Stockholm city. One of the particularities of Sweden is that Sweden's cities are not administrative units as such. Sweden only has communes and many of them are extremely large in size. We therefore do not have to be particularly concerned with changes in administrative boundaries. Furthermore, given Sweden's particular economic geography as a very sparsely settled country with large geographic distances between towns, we do not have the issue of cities merging with one another, as one might have in continental Europe. We rely on the formal definition of a town as granted by royal charter, but we have also added a number of localities as defined by the Swedish statistics office to the sample, using a population threshold of 10,000 inhabitants as of 2010.

6. Empirical analysis

6.1 Primacy ratios

In order to get a first sense of the degree of population dispersion in the Swedish city network over time, we calculate primacy ratios for all the decades in our sample and compare the actual results with the hypothetical numbers that would occur if the rank-size relationship was holding up exactly. Following Rosen and Resnick (1978), primacy I is defined as the share of Stockholm's population among the top five cities while primacy II is defined as the share of Stockholm's population in the top 50 cities in the urban network. Under the hypothetical Zipf's law relationship, with the nth city being 1/n the size of the largest city in the urban hierarchy, primacy I should assume a value of 44% while primacy II should assume a value of 22%.

Our results summarised in table 2 below clearly show that Sweden is a country with one single primate city, the capital Stockholm, and this has been the case for several centuries. In an earlier version of the paper, we had also calculated primacy ratios for the early modern period. They were assuming an even higher value before 1810 due to the fact that Stockholm was the only large city in Sweden at the time while most other cities had not more than a few hundred to a couple of thousand inhabitants before the Industrial Revolution. Stockholm was thus a clear primate city during the early modern period when the country was still extremely rural. Moreover, Stockholm was also growing at a more rapid pace than the rest of the country. Consequently, primacy I and primacy II were reaching an absolute high of more than 70% and 40%, respectively, in the late 1600s.

After 1810, one can observe a steady and marked decline over the next two centuries as both primacy ratios were reaching an absolute low of less than 50% and 27%, respectively, by 1920. This trend was the obvious result of rapid city growth and urbanisation at the national level, as the cities following

Stockholm in the national rank size distribution were now expanding faster than the capital itself, especially once the country started to industrialise during the late 19th century. However, in recent decades one can detect an increasing tendency towards a distribution with one primate city again, given that Stockholm has reasserted its dominant position in the Swedish urban hierarchy. Primacy I rises from 1940 onwards whereas primacy II increased after 1970 as well, albeit by not quite as much.

The higher degree of stability of Stockholm in the top 50 population share compared to the top five population share implies that the overall city network is more stable than just the upper end of the city size distribution. In fact, our primacy III ratio where we calculate the five largest cities' population shares in the top 50 cities in the urban network is remarkably stable over the course of the two centuries under consideration. And more importantly, it is also in line with what one would expect if the urban hierarchy was obeying the rank-size rule.

We can thus conclude that the dominance of Stockholm in the Swedish city network has to some extent come at the expense of the other large agglomerations in Sweden, which are in decreasing order of importance as of today: Gothenburg, Malmö, Uppsala, and Västerås. We will see below that the cities that immediately follow the Swedish capital in the rank-size distribution actually have smaller population levels than implied by the Zipf's law benchmark throughout most of the time periods that we cover in our analysis.

6.2 Zipf's law for Swedish cities

As summarised above, Zipf's law posits a simple linear relationship between city size in terms of population and city rank in the national distribution. Usually, the relationship is expressed in natural logarithms by the following equation:

$$(1)\quad \ln(S_i) = \beta_1 + \beta_2 \ln(rank_i) + \varepsilon$$

where $\ln(S_i)$ denotes the logarithm of city size as measured by its total population and $\ln(rank_i)$ denotes the logarithm of its rank in the national city size distribution. We estimate equation (1) using regular Ordinary Least Squares (OLS) for our sample of Swedish cities for each decade separately for which we have available data, 20 decades in total starting in 1810. Our sample size gradually increases as the number of cities in the Swedish urban network almost doubles from 92 in 1810 to 160 in 2010.

However, some studies have found that the OLS estimator can be biased when estimating the Zipf's law regression as presented above. This is especially the case if the sample size is small, which certainly applies to our analysis, given that the Swedish city network only consisted of some 90 cities in the early 1800s. Furthermore, the OLS regressor is not very robust to outliers (Dittmar, 2011). We have also established above that Stockholm is a relative large outlier in the city size distribution. Moreover, Sweden's unique characteristic is that it has a number of relatively small towns, which also seem to be outliers at the bottom half of the distribution. We therefore also estimate equation (1) using the Theil-Sen (Theil, 1950; Sen, 1968) median slope estimator (MSE) suggested by Dittmar (2011) for an analysis of Zipf's law. While the median slope, i.e. the slope of the 50th percentile, should be comparable to our OLS estimator, the MSE has the advantage that it is more robust to outliers than the standard OLS regressor. Moreover, the slope estimator also allows us to calculate the Zipf's law coefficient for different percentiles in the rank-size distribution, which will allow us to detect non-linearities in the sample. We can therefore also analyse the slope coefficient for different percentiles of the city size distribution.

Figure 1 below displays the Zipf's law coefficient for all Swedish cities in our sample from 1810 to 2010. The graph displays the results from the OLS regression as well as the 95% confidence intervals around the estimator. We have also included the results from the median slope estimator with a similar confidence interval. One can see that the two estimation methods yield slightly different results. More specifically, the Zipf's law coefficient obtained with regular OLS seems to be biased downwards for most of the time period. It is only by the early 20th century when the overall sample size has more than doubled that the two estimation methods yield almost the same coefficient. However, the difference between the two regressors does not seem to be very sizeable most of the time, with the exception of the time period spanning from about 1840 to 1910. More importantly, the direction of change for the two coefficients is extremely similar over the time span of 200 years under consideration.

Both the OLS and the MSE estimator show that the Zipf's law coefficient for the Swedish city network was relatively close to the magical number of one in the beginning of the 19th century, meaning that the Swedish urban hierarchy followed the rank-size rule during that time. However, one can also observe that the Zipf's law coefficient increases continuously throughout the

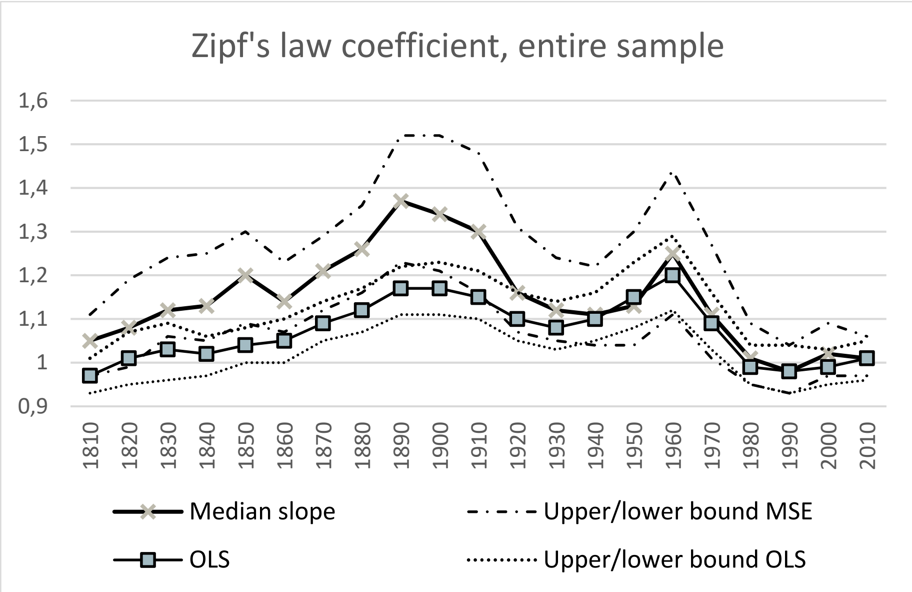

Figure 1:
Source: Author's calculation

entire 19th century. The MSE estimator shows a much steeper increase in the coefficient in comparison to regular OLS. The MSE estimator increases from a low of 1.05 in 1810 to reach an absolute peak of 1.37 in 1890, only to start decreasing again thereafter. With the exception of a short spike in the middle of the 20th century, the Zipf's law coefficient displayed a continuous downward trend over the course of the 20th century and has approached unity again in 2010.

While for most periods we can reject the null hypothesis that the coefficient is equal to one using a simple F-test, we have emphasized before that we are more interested in the direction of change over time than the exact size of the coefficient. As suggested by Gabaix (1999a), we can certainly confirm that our Zipf's law coefficient belongs to the relatively narrow range of 0.8 to 1.2 most of the time, with the period of Swedish Industrial Revolution in the late 19th century from about 1870 to 1920 being the notable exception.

As explained by Venables (2005), a low Zipf's law coefficient indicates a higher degree of population dispersion in the urban system. That is because with a flatter slope in equation (1), city size decreases more slowly as one goes down the ranks in the urban hierarchy, meaning that cities are more equal in size than what the rank-size rule suggests (Venables, 2005). Similarly, a very steep slope indicates a very unequal urban hierarchy in terms of city population size.

It is ultimately not very surprising that the Zipf's law coefficient was relatively low before the outset of the Industrial Revolution, thus indicating that Sweden's urban population was more dispersed during that time. This makes sense insofar as the degree of market integration was quite low. The country's urbanisation rate did not even reach 10% of the total population well after 1800. The urban network was thus characterized by the presence of many small towns with relatively equal size, barely reaching a couple of thousand inhabitants at the time.

The Zipf's law coefficient increases sharply over the course of the 19th century, which corresponds to the time period when the country began to develop and industrialise quite rapidly. As for the urban hierarchy, peak concentration in terms of the rank-size rule was already reached by the beginning of the 20th century with the MSE yielding a Zipf's law coefficient even exceeding 1.2 during that time period. It is a somewhat surprising result that the Zipf's law coefficient has shown a steady and continuous decline over the last century, thus indicating a tendency towards increasing population dispersion in the urban network today compared to one hundred years ago. This finding seemingly contradicts many economic studies that have shown increasing agglomeration effects in many economies, since it basically implies that in terms of the urban hierarchy Swedish cities have actually become more equal in size.

We might be able to explain this effect as a result of selection bias, given that the city network has continuously expanded over time, since a number of small but rapidly growing localities have been added to our sample. Take the example of the town of Lomma near Malmö, which had less than 4,000 inhabitants in the 1960s, but already more than 10,000 inhabitants as of 2010, corresponding to a decennial growth rate of more than 20%.

Given that our sample size almost doubles in between 1810 and 2010 as we add new cities to our sample over the course of two centuries, it is possible that we have introduced some kind of bias in our previous estimation. There is thus some concern that we might potentially skew the rank-size rule by adding small but potentially above-average growing cities at the bottom of the distribution to the urban hierarchy. We therefore also

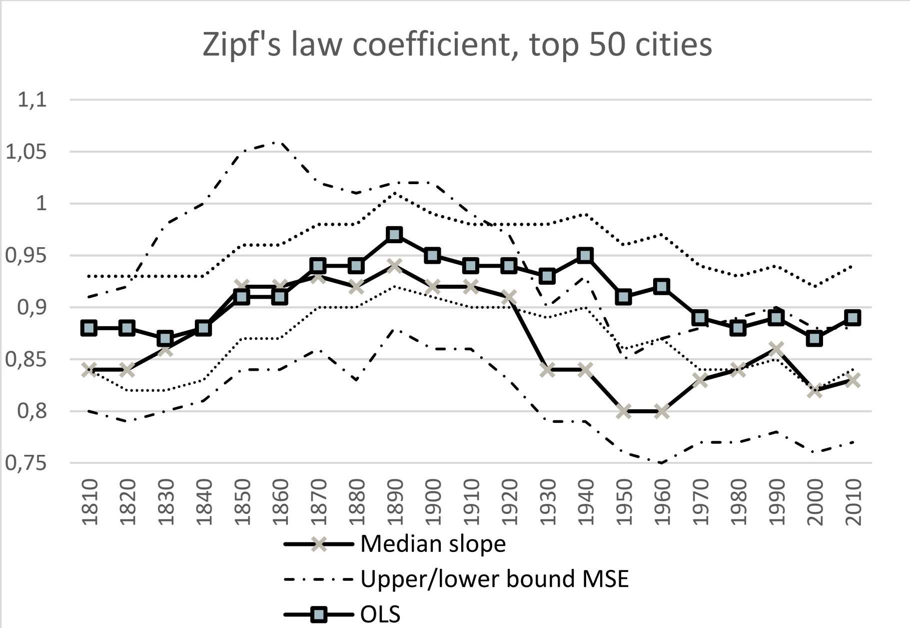

Figure 2:
Source: Author's calculation

estimate Zipf's law for each decade, but now holding the sample size constant over time by only including the 50 largest cities for each decade in the regression. Obviously, over the course of 200 years there is a relatively high degree of churn in the city size distribution. Consequently, selection into and out of the top 50 cities might be an issue as well.

Figure 2 displays the results for the Zipf's law coefficient for the restricted sample size of the largest 50 Swedish cities. It is obvious that excluding the smallest towns must mean a more equal distribution in general, thus shifting the Zipf's law coefficient downward. Restricting the sample size to the upper part of the city size distribution thus produces a significant decline in the coefficient, which shifts well below unity for all decades under consideration. We can now reject at all significance levels that the Zipf's law coefficient is equal to one using either the MSE or standard OLS. However, what is of more interest to us again is the direction of change of the coefficient over time.

At the start of the 19th century, the Zipf's law coefficient assumes a relatively low value below 0.9, regardless of whether it is estimated using the OLS regressor or the MSE approach. It subsequently rises over the next 100 years to reach a peak of about 0.97 by 1890. Finally, it decreases in size again over the next hundred years to reach a value below 0.9 as of today. Furthermore, while both the OLS and the MSE yield similar results for the 19th century, the two estimation methods start to diverge somewhat after 1900, with the MSE yielding a steeper decline in the coefficient over the last 100 years. However, our new results show that restricting the sample size does not substantially alter our conclusion. Even within the top 50 cities in Sweden, peak concentration in terms of the rank-size rule was reached during the period of industrialisation in the late 19th century. Again, it is somewhat surprising that over the course of the 20th century the city size distribution has actually become more equal as the Zipf's law coefficient declined, thus indicating that the urban population became more dispersed using this particular benchmark. This result is in contrast with the assertion that there has been an increasing tendency towards population concentration in recent decades as a result of agglomeration effects. While the increasing dominance of Stockholm as a metropolitan area cannot be denied, the story seems to be more nuanced when one considers the entire city size distribution. We will see below that in the Swedish case cities in the lower end of the distribution have actually experienced higher growth rates over the last 100 years, which had the effect of pulling down the Zipf's law coefficient. City sizes in the urban hierarchy therefore became more equally distributed.

6.3 Deviations from Zipf's law

Some authors have argued that the adherence of the city size distribution to a power law is an indicator of the degree of market integration (Dittmar, 2011). More specifically, restrictions to population movements, such as serfdom in the early modern period in Eastern Europe or other forms of barriers to goods market For every city in the urban network, we measure the difference between its actual population and its Zipf-consistent population where the latter is simply the predicted value estimated by the OLS regression of equation (1). We then calculate the mean squared deviation for each decade as an indicator that measures to what extent the actual city size distribution deviates from the hypothetical power law. Table 2 contains the historical deviations from Zipf's law for every decade in our sample, both for the entire sample and for our restricted sample of the top 50 cities.

Table 2:
Mean squared deviation from Zipf's law and primacy ratios

Year	Mean squared deviation (entire sample)	Mean squared deviation (n=50)	Primacy I (1/5)	Primacy II (1/50)	Primacy III (5/50)
Zipf-consistent ratio			43.8%	22.2%	50.7%
1810	2.4%	1.6%	62.2%	32.5%	52.2%
1820	4.2%	1.9%	62.8%	32.9%	52.5%
1830	4.4%	1.7%	61.1%	31.6%	51.8%
1840	3.5%	1.5%	59.6%	30.6%	51.3%
1850	3%	1.1%	57%	28.6%	51.2%
1860	4%	1.1%	55.2%	28.6%	51.7%
1870	4%	0.9%	52.7%	27.6%	52.5%
1880	5.1%	0.8%	51.3%	26.6%	51.8%
1890	5%	0.8%	54.1%	29.5%	54.5%
1900	6.5%	0.9%	53.4%	29.2%	54.6%
1910	7.2%	0.8%	50.7%	26.9%	53.0%
1920	6.3%	0.8%	49.9%	27%	54.2%
1930	6.3%	1.1%	51.1%	28.5%	55.8%
1940	7.2%	1%	50.9%	28.2%	55.5%
1950	16.7%	1.3%	51.5%	27.5%	53.5%
1960	20.8%	1.5%	53.3%	28.8%	54.0%
1970	13.7%	1.1%	50.6%	25.9%	51.2%
1980	7.1%	1.1%	52.8%	27%	51.1%
1990	6.7%	1.2%	53.7%	27.6%	51.4%
2000	6.2%	1.4%	55.5%	29.1%	52.4%
2010	6.4%	1.4%	55.9%	29.9%	53.4%

Source: Author's calculation
Mean squared deviations are defined as: $MSD = N^{-1}\sum_{i=1}^{N}(\frac{S_i}{S_i^z} - 1)^2$ where S_i^z is the Zipf-consistent population" (predicted population) computed from the OLS estimator based on regression (1)

One can see that the deviations from the power law increase over time as the sample size increases, reaching a peak of more than 20% in the 1960s. This result is not very surprising. A large body of literature suggests that Zipf's law does not hold well in the lower part of the city size distribution. More specifically, small towns are usually not large enough to fit the rank-size rule well (Gabaix, 1999a). We also detect such non-linearities in the Swedish data as population size decreases much faster in rank once you reach the lower part of the distribution, i.e. city population levels literally fall off a cliff as soon as all small towns are included in the sample.

It is therefore more interesting to observe the deviations from the power law, holding our sample size constant at 50 observations. The results are in line with our expectations, namely that deviations from Zipf's law were larger during the early modern period and the beginning of the 19th century before the Industrial Revolution when market integration was low. More specifically, deviations from Zipf's law decrease from about 2% in the early 1800s to less than 1% by the beginning of the 20th century (table 2).

Holding the city size sample constant, the mean squared deviations from Zipf's law then decrease rapidly during the 19th century. This corresponds to the time period during which we can also observe increasing convergence in Swedish regional GDP series and wages (Enflo and Missiaia, 2017), thus again pointing towards a correlation between regional market integration and Zipf's law.

6.4 The emergence of the power law

A number of studies suggest augmenting the estimation for Zipf's law by adding a quadratic term for the logarithm of city population to the regression in order to detect non-linearities and deviations from the distributional power law (Dittmar, 2011). Gabaix (2008) has developed a more elaborate test to determine whether the city size distribution follows a power law and proposes to estimate the following equation:

$$(3)\quad \ln(rank_i - 0.5) = \beta_1 + \beta_2 \ln(S_i) + \beta_3 \ln(S_i - {S^*}_i)^2 + \varepsilon$$

where $\mathrm{S}^* = \mathrm{cov}\,[(\ln(\mathrm{S_i})^2, \ln(\mathrm{S_i}))/\,2\,\mathrm{Var}\,(\ln(\mathrm{S_i}))]$ and the shift factor of -1/2 provides the optimal reduction for the small sample bias in the OLS regression. The second term in the regression is a quadratic term that is supposed to capture non-linear deviations from a power law distribution. Using the Gabaix test, we reject the null hypothesis of a power law with a 95% confidence interval if and only if

$$(4)\quad |\hat{\beta}_3/\hat{\beta}_2{}^2| > 1.95 * (2n)^{-0.5}$$

Dittmar (2011) uses equation (2) to estimate Zipf's law for early modern Europe. His analysis shows that we can reject Zipf's law up through 1500, but not thereafter. The institutional setting was very different in Eastern and Ottoman-controlled Europe. Cities in Western Europe benefitted from a distinct institutional environment. Town charters in the West guaranteed townspeople legal property rights and freedom from serfdom, which fostered geographic mobility and the growth of urban commerce (Dittmar, 2011). Some authors have emphasized that the Elbe river was an institutional boundary between Western and Eastern Europe. Serfdom was strengthened in Eastern European after the Black Death ravaged through Europe during the 14th century, killing as much as half of the population in some regions (North, 1973). Labor scarcity then led to the emergence of restrictive and exclusive economic institutions. Specific laws were introduced, which tied tenant farmers to rural estates and limited commercial activities by urban merchants. The institutions that emerged in Eastern Europe, especially serfdom, thus restricted geographic mobility (North, 1973). All these distortions also had an impact on the city size distribution, as they prevented the development of a single, integrated urban system. According to Dittmar's (2011) analysis, Zipf's law in Eastern Europe does not hold until about 1800.

Sweden can be classified as an intermediate case. In terms of the institutional setting, the country definitely belongs to the West as feudalism was never fully established in the Nordic countries and serfdom did not exist during the early modern period. However, in terms of market integration, Sweden was overwhelmingly rural and less densely populated than continental Europe.

Following Gabaix (2008) and Dittmar (2011), we estimate the power law for the Swedish city network for all decades with OLS using equation (2). The results of the regressions, including the Gabaix test, are displayed in table 3. We can see that the power law is rejected for the early 19th century when national market integration was still extremely low and Sweden's urbanisation rate had not even reached 10%. According to this analysis, Zipf's law starts to hold only by the mid-19th century. More surprisingly, the power law can also be rejected from 1980 onwards. This deviation from the power law at the end of the 20th century can be explained by the fact that a

Table 3:
Power law test based on Gabaix (2009a), entire sample

Year	n	β_2	β_3	$(\beta_3/\beta_2$^2)	1.95(2n)^-0.5	Reject
1810	92	-0.734***	-0.068***	-0.126	0.144	NO
1820	94	-0.787***	-0.108***	-0.175	0.142	YES
1830	95	-0.916***	-0.118***	-0.141	0.141	YES
1840	95	-0.800***	-0.099***	-0.154	0.141	YES
1850	96	-0.870***	-0.096***	-0.127	0.141	NO
1860	100	-0.952***	-0.108***	-0.119	0.138	NO
1870	101	-1.209***	-0.105***	-0.072	0.137	NO
1880	101	-1.542***	-0.115***	-0.049	0.137	NO
1890	102	-1.801***	-0.101***	-0.031	0.137	NO
1900	106	-2.003***	-0.108***	-0.027	0.134	NO
1910	118	-1.969***	-0.112***	-0.029	0.127	NO
1920	125	-1.517***	-0.109***	-0.047	0.123	NO
1930	127	-1.350***	-0.103***	-0.056	0.122	NO
1940	130	-0.926***	-0.107***	-0.124	0.121	YES
1950	143	-2.210***	-0.130***	-0.027	0.115	NO
1960	155	-3.955***	-0.128***	-0.008	0.111	NO
1970	159	-4.113***	-0.134***	-0.008	0.109	NO
1980	159	-0.786***	-0.116***	-0.188	0.109	YES
1990	160	-0.786***	-0.124***	-0.200	0.109	YES
2000	160	-0.759***	-0.109***	-0.189	0.109	YES
2010	160	-0.885***	-0.107***	-0.137	0.109	YES

Source: Author's calculation
*,**,*** designate the usual 10%, 5%, and 1% significance level, respectively

number of small cities have been added to the Swedish urban network in recent decades. These rather low-population localities are ultimately too small to obey the rank-size rule. We will see below that the city size distribution experiences quite significant non-linearities, both at the upper and the lower end of the distribution where the Zipf's law coefficient deviates significantly from unity.

We test this hypothesis by also estimating equation (4) only for the largest 50 cities in Sweden and find that the power law holds for each decade from 1810 to 2010 in our study when the urban network is restricted to a smaller size (table 7 in the appendix). We can therefore conclude that it is indeed the small localities that lead to the fact that Sweden does not obey the power law in the beginning of the 19th century and in the end of the 20th century.

6.5 Non-linearities in the city size distribution

Some studies have shown that the power law for cities displays important non-linearities, especially in the lower part of the city size distribution where population levels are very small (Dittmar, 2011). We therefore also use the Theil-Sen percentile slope estimator and estimate the Zipf's law coefficient for each decade for different percentiles in the city size distribution, using the 15th, 30th, 50th, 70th, and 85th percentile respectively. One should keep in mind that the percentiles are ranked according to population levels. A higher percentile corresponds to a larger city and therefore a higher rank in the city size distribution.

The findings based on the Theil-Sen slope estimator are in line with our expectations. The coefficient increases in size in absolute values as one goes down the ranks in the city size distribution. The slope is therefore relatively flat in the upper part of the city size distribution and becomes steeper and steeper as cities get increasingly smaller. This result holds up throughout the entire time period under consideration from the late 19th century until today.

We consistently find a slope coefficient below one in absolute values in the upper part of the city size distribution (for the 85th percentile slope). This result is indicative of the fact that the large Swedish cities are more equal in size then they should be according to the power law, with the exception of Stockholm being the primate city throughout the entire time period. The Zipf's law coefficient is relatively stable between 0.8 and 0.9 for the 85th percentile slope for most of the 200 years of data under consideration, with the exception of a short spell in the mid- and late 19th century when the coefficient approaches unity in the upper part of the city size distribution.

In the lower part of the city size distribution, on the other hand, we consistently find percentile slopes significantly larger than one in absolute values. As one can see from the table, the Zipf's law coefficient for the 30th and 15th percentile slope for the Swedish city size distribution is consistently exceeding unity by a large margin for the entire 200 years of data. Moreover, the big linearity always seems to occur between the 30th and the 15th percentile slope, as the Zipf's law coefficient dramatically increases between those two percentiles slopes. Again, this result is extremely robust for the two centuries of data at hand. The 15th percentile slope is assuming a value of about 1.8 in the early 1800s. The coefficient then increases over time to reach a value that exceeds 2 by the mid-20th century, only to decrease to about 1.8 again by the late 20th century. The extremely high value of the percentile slope indicates that cities in the lower part of the city size distribution are decreasing much faster in population levels than what Zipf's law suggests. This phenomenon is especially pronounced in the beginning and middle of the 20th century when an increasing number of small cities were added to the Swedish urban network, thus distorting the rank-size rule at lower ranks.

6.6 Zipf-consistent population levels

We have noted above that the Swedish city network displays a higher degree of population dispersion than predicted by Zipf's law, especially if one restricts the sample size to the 50 largest cities in the sample, which yields a Zipf's law coefficient that is consistently below unity. We will now see that this result is due to the fact that most of the large cities in Sweden punch below their weight in terms of actual population size whereas many cities in the middle of distribution are consistently larger than expected if one considers Zipf's law to be the hypothetical benchmark. Again, this result shows a remarkable stability over the course of several centuries.

Using primacy ratios, we have shown that Sweden's urban network has been characterized by one primate city, Stockholm. While the dominance of the capital was extremely prevalent during the early modern period and receded over the course of the 19th century, the obvious result of rapid city growth and urbanisation on the national level as the country started to industrialise rapidly, Stockholm's relative size has reasserted itself in recent decades.

We support this result by estimating so-called Zipf-consistent population levels for all Swedish cities, which is simply defined as the predicted population $\hat{S}_i$ obtained from the OLS regression of equation (1). Table 4 below summarises the results from comparing a city's actual population to the

Table 4:
The ratio of a city's actual population to its Zipf's law consistent population for the top 10 Swedish cities

	City Rank									
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1810	1.65	0.71	0.78	0.87	0.69	0.79	0.71	0.80	0.86	0.84
1820	1.51	0.66	0.70	0.78	0.71	0.82	0.68	0.72	0.74	0.77
1830	1.36	0.72	0.61	0.70	0.77	0.83	0.67	0.65	0.73	0.76
1840	1.33	0.69	0.62	0.81	0.83	0.80	0.69	0.69	0.77	0.79
1850	1.20	0.69	0.68	0.77	0.90	0.77	0.68	0.75	0.84	0.85
1860	1.14	0.78	0.64	0.82	0.84	0.73	0.66	0.76	0.82	0.85
1870	1.00	0.88	0.63	0.80	0.71	0.72	0.71	0.78	0.87	0.85
1880	0.88	0.87	0.69	0.67	0.60	0.72	0.75	0.85	0.89	0.82
1890	0.92	0.88	0.65	0.62	0.58	0.65	0.75	0.87	0.96	0.83
1900	0.87	0.86	0.64	0.61	0.57	0.59	0.69	0.78	0.88	0.96
1910	0.82	0.89	0.71	0.55	0.54	0.63	0.68	0.75	0.83	0.92
1920	0.93	0.96	0.85	0.60	0.62	0.61	0.69	0.68	0.76	0.83
1930	1.05	1.08	0.83	0.58	0.67	0.57	0.66	0.75	0.75	0.79
1940	0.99	1.01	0.88	0.55	0.62	0.59	0.70	0.68	0.75	0.83
1950	0.85	0.82	0.72	0.44	0.48	0.56	0.63	0.69	0.77	0.82
1960	0.74	0.79	0.66	0.37	0.42	0.52	0.62	0.71	0.73	0.83
1970	0.85	0.91	0.77	0.40	0.51	0.60	0.66	0.70	0.78	0.85
1980	1.19	1.09	0.81	0.49	0.58	0.64	0.69	0.75	0.82	0.90
1990	1.26	1.11	0.80	0.52	0.58	0.63	0.69	0.76	0.81	0.89
2000	1.29	1.05	0.79	0.52	0.54	0.61	0.69	0.74	0.78	0.85
2010	1.3	1.04	0.8	0.54	0.53	0.62	0.7	0.75	0.77	0.84

The ratio corresponds to S_i/S_i^z where S_i is the actual population and S_i^z is the "Zipf-consistent population" (predicted population) computed from the OLS estimator based on the entire sample.

estimated Zipf-consistent population for the top 10 Swedish cities for every decade in our dataset. The ratio thus obtained gives us an indication of a city's actual size compared to the Zipf's law benchmark.

Our results confirm the clear dominance of the Swedish capital. Its actual population is substantially higher than its Zipf-consistent population for almost the entire two centuries of data, with the exception of a short spell in middle of the 20th century. For the early 19th century, we find that Stockholm is some 40 to 60% larger than its Zipf consistent estimate. The ratio then starts a steady downward decline to reach an absolute low of less than 0.8 in the 1960s. However, it subsequently recovers and as of today easily exceeds unity again with a value of 1.3 in 2010.

Besides Stockholm continuously exceeding its benchmark, the other striking fact about Sweden is that the large cities that follow Stockholm in the Swedish rank-size distribution are consistently smaller than what their Zipf-consistent estimate implies, with the notable exception of Gothenburg, which is approaching its Zipf-consistent estimate by the end of the 20th century. However, the subsequent cities in the rank-size distribution following Stockholm and Gothenburg are some 20 to 40% too small relative to the benchmark. On the other hand, many cities in the middle and at the end of the population distribution are actually exceeding their Zipf-consistent estimate and are therefore larger than predicted by the Zipf's law. Sweden is thus a clear case with an urban hierarchy having one primate city, Stockholm, followed by a number of cities in the upper part of the rank-size distribution that are relatively small whereas small cities in Sweden consistently exceed their Zipf-consistent population estimate.

We also check the previous results for robustness and re-estimate the Zipf-consistent population levels based on the constant sample size of the 50 largest cities in Sweden. While Gothenburg and Malmö are now also slightly larger than their Zipf-consistent estimate by the end of the 20th century, all subsequent seven cities in the Swedish rank-size distribution remain much smaller than what the power law predicts. This result holds throughout the entire time period from the early 19th century to today (see table 9 in the appendix). Moreover, this finding is also robust to using the MSE instead of the standard OLS regression to compute Zipf-consistent population level.

We can thus conclude that most of the larger cities in Sweden, with the exception of Stockholm being the primate city as well as Gothenburg and Malmö by the end of the 20th century, are considerably smaller than implied by Zipf's law whereas Swedish cities in the middle of the distribution are somewhat larger than implied by the benchmark. This finding is relevant insofar as an increasing amount of economic literature supports the notion that productivity is positively correlated with population density and city size (Glaeser, 2012). The Swedish deviations from Zipf's law might imply a suboptimal distribution of the urban population on the national level, as the large cities in Sweden following Stockholm in the rank-size distribution are too small relative to the benchmark. High house prices in the large agglomerations, for example, could prevent a reallocation of labor towards the high-productivity areas, a hypothesis we revisit in more detail below.

6.7 Gibrat's law and random growth theory

It is still left to be determined why the power law for cities actually emerges within some geographic areas of a certain size. Krugman (1993b) initially suggested that Zipf's law occurs as the result of natural landscapes being randomly distributed throughout space, thus also giving rise to randomly varying transport costs. This explanation has the obvious advantage of providing an economic rationale for the emergence of the city size distribution: Geographic fundamentals tie down the spatial distribution of economic activity by affecting transport costs. From a strictly mathematical point of view, researchers have shown that power laws occur naturally as a result of a stochastic growth process (Gabaix, 1999b). Simon (1955) was one of the first to suggest that Zipf's law ultimately emerges if cities follow a random growth process, a proposition that is also known as Gibrat's law (Klein and Leunig, 2015).

Following Klein and Leunig (2015), we use a nonparametric regression to estimate the relationship between initial population size and subsequent city population growth. While random growth theory asserts that no such a relationship exists in the medium to long-run, increasing agglomeration forces would suggest a positive relationship between city size and growth rates.

The advantage of the nonparametric estimator is that it allows the data to speak for itself, since we are uncertain about the exact functional form of the mean of the outcome given the covariates (Altman, 1992). As there are reasons to believe that the relationship between city size and city growth rates is non-linear, a nonparametric estimate seems to be well suited for the analysis at hand. While such a regression relies on a sufficient number of data points and the Swedish city network is ultimately not very large, introducing the time component allows us to easily exceed a few hundred observations, which are usually deemed to be sufficient for this method to be applicable (Altman, 1992). We thus estimate the following equation using the Epanechnikov Kernel estimator with 1000 bootstrap replications to determine the relationship between city size and growth rates:

$$(3)\ city\ population\ growth = f(city\ rank) +\ \varepsilon$$

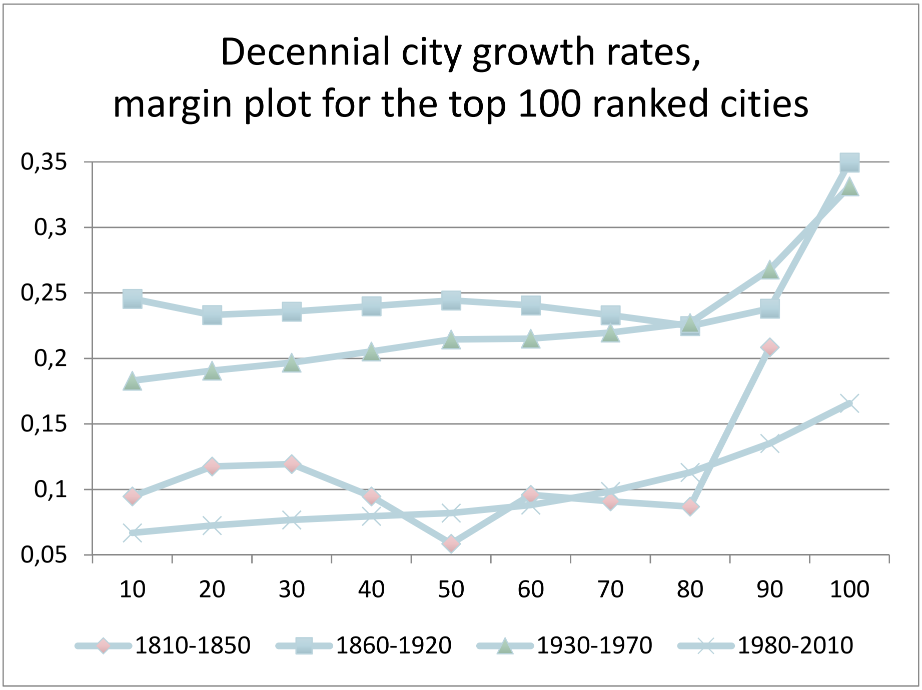

Figure 3:
Source: Author's calculation

The advantage of this method is that it does not assume that the function f(...) is linear. The relationship between city growth and city rank can thus assume any functional form and is left to be determined by the data. We have split up the sample into four different time periods for the 200 years in question to perform the regression: The pre-industrial period from 1810 to 1850, the period from 1860 to 1920 that basically comprises the Swedish Industrial Revolution, the early and mid-20th century from 1930 to 1970, and finally the post Bretton Woods period from 1980 onwards. As a second step, we estimate the marginal change of an increase in city size on subsequent population growth rates by calculating the margin plot for every 10 step increase in city rank, again using 1000 bootstrap replications.

Figure 4 above shows the predicted average city population growth rate from rank 10 to 100 in the city size distribution for the different time periods mentioned above. Especially for the pre-industrial period from 1810 to 1850, we find that average city growth rate is a decreasing function of city rank, meaning that larger cities were growing at a more rapid pace than small cities.

While still present, the effect is already less pronounced during the time period of the Industrial Revolution. Surprisingly, we find that the relationship reverses during the 20th century. For the last two periods from 1930 to 1970 and from 1980 to 2010, we find a strictly positive relationship between average city growth rate and city rank. Cities in the lower part of the city size distribution have consistently been growing faster than average during the last 100 years, thus casting some doubt on the popular narrative that agglomeration effects have been the dominating force in today's economic geography in Sweden.

Using the margin plot, we therefore detect a slightly negative relationship between average growth rates and city rank throughout the 19th century. During the 20th century, on the other hand, the relationship completely reverses as cities in the lower part of the city size distribution now grow significantly faster. Moreover, our analysis also seems to provide some evidence against random growth theory, the hypothesis that city rank and city growth rate should be uncorrelated in the long-run and that population growth is determined stochastically. At least for the Swedish case, we find some tentative evidence against random growth. This, in turn, can also explain why for the end of the 19th century the Zipf's law coefficient for the Swedish city network exceeds the aforementioned maximum upper boundary of 1.2 suggested by Gabaix (1999a). A lot of research suggests that the Zipf's law coefficient arises as a result of a stochastic growth process in the long-run. However, as we have shown above, we find some evidence against random growth during the 19th century with larger cities growing faster than average, thus leading to more population concentration at the top of the distribution and pushing the coefficient upward. It is therefore not surprising to find deviations from Zipf'slaw during that period. Vice-versa, the positive relationship between city rank and city growth rates during the last century has had the opposite effect of pushing the Zipf's law coefficient downward and towards unity, therefore leading to a more equal distribution within the Swedish urban hierarchy and thus casting some doubt on the popular narrative that agglomeration effects have increased significantly in size in recent decades.

7. Discussion of results

The academic literature supports the notion that city size is correlated with productivity and other meaningful economic variables (Glaeser et al., 2016). This is not surprising. Bettencourt et al. (2007) explain how cities economise on inputs. Road surface, the number of gas stations, the lengths of electric cables, and other important infrastructures, commonly have a scaling factor below one whereas measures of output, such as patent production, wages, or even wealth are scaling superlinearly with city size. The economisation of inputs combined with economies of scale in the production process are creating the agglomeration forces that lead to the emergence of large cities and metropolitan areas (Krugman, 1991). In recent decades, the emergence of the knowledge economy has arguably increased certain agglomeration effects, as suggested by Moretti (2012). While some economic forces thus continue to push towards rising concentration, there are also forces of dispersion that push in the other direction, most notably congestion effects and rising house prices. According to Ellis and Andrews (2001), it is the balance of these opposing forces that creates a complex spatial equilibrium between cities, leading approximately to the power law distribution in the urban hierarchy. While random growth theory simply posits that the power law simply emerges as a result of a stochastic growth process (Simon, 1955), the result is not very appealing from an economic point of view because the precise nature of growth process is being left undetermined, a black box so to speak. Davis and Weinstein (2008) have argued that the strong recovery of Japanese cities after their destruction during World War II speaks in favour of locational fundamentals, i.e. that geographic endowments are the driving force behind the determination of the spatial equilibrium. Similarly, Enflo and Berger (2015) find that regional population shocks can have persistent effects.

For Sweden, we observe a relatively high autocorrelation coefficient for city rank on a 40-year interval for the entire time period under consideration. The autocorrelation moves around in a relatively narrow interval of 84% to 95% from 1810 until today (see table 10 in the appendix). The relative position of the top three agglomerations, Stockholm, Gothenburg, and Malmö, has remained unchanged since the late 18th century. However, geography is not destiny and locational fundamentals also change according to evolutions in transport technology and other economic and historic developments. The city of Visby, for example, was extremely important during the Late Middle Ages as a trading post and fortification on the island of Gotland in the Baltic Sea during the peak influence of the Hanseatic League. However, the city increasingly became marginalised during the early modern period as a result of its geographic remoteness and disappeared from the top 10 Swedish cities by 1830 altogether. While Gothenburg was always among the top 10 cities in Sweden, its relative size increased only as a port on the Western Seaboard of Sweden during the end by the 18th century and especially during the 19th century. The city consolidated its rank as the second agglomeration in Sweden by the late 1700s, since it benefited from the first wave of globalization. Easy access to world markets as well as trading restrictions meant that the Swedish East Company could only operate from the port of Gothenburg.

Our rank analysis also shows that the relative position of the cities following Stockholm, Gothenburg, and Malmö has been quite dynamic over time. We have established that the large cities in Sweden from rank four to 10 have historically been much more equal in size than what the simple power law predicts, thus leading to a very flat percentile slope in the upper end of the city size distribution. Consequently, one can also observe a relatively high amount of churn as those cities actively compete against each other. Small regional shocks can thus easily upset even the upper end of the rank-size distribution. The city of Norrköping, for example, entered a period of relative decline as the textile industry closed down shortly after World War II. Meanwhile, the neighboring city of Linköping some 40 km apart rose in rank in the top 10 Swedish cities. The foundation of the University in the early 1970s and the location of high-tech industry meant that in terms of regional population growth Linköping fared much better than its struggling neighbor in recent decades.

Considering a time period 200 years, we find evidence against random growth theory. Even for the 20th century, we can confirm a positive relationship between initial rank and subsequent population growth, thus giving rise to a more unique city size distribution with most of the large Swedish cities behind Stockholm punching below their weight in terms of their Zipf-consistent estimates. Not only are many medium-sized cities in Sweden too large relative to the benchmark, but they are also growing at a more rapid pace. This peculiarity of the Swedish city size distribution led to a marked drop of the Zipf's law coefficient over the course of the 20th century. Given the strong relationship between population size and productivity, the relative size disadvantage of the larger cities in Sweden except for Stockholm might even have macroeconomic implications. As such, the country's suboptimal city size distribution could potentially have a negative effect on economic growth. Moretti and Hsieh (2015), for example, estimate that increasing housing supply in the high-income states on the US West coast might result in a sizeable increase in potential output. More elastic housing supply in the large agglomerations in Sweden could therefore have similar benefits. Furthermore, Ellis and Andrews (2001) assert that the city size distribution within a country also affects the housing market. Holding the population level fixed, an increase in the primacy ratio implies higher national house prices. We have documented above that Sweden does not strictly follow the standard power law in the upper tail of the distribution as Stockholm, being the primate city, is consistently larger than predicted by the benchmark. Moreover, the agglomerations of Gothenburg and Malmö have also gained ground relative to their Zipf-consistent populations in recent decades. In line with that prediction, data from the Jorda, Schularick and Taylor Macrohistory database (2017) confirms that real house prices in Sweden have outpaced real estate prices in many other advanced economies in recent decades, with most of the price appreciation taking place over the last 30 years. While it is true that house prices in the three metropolitan areas have outperformed national house prices in Sweden by a large amount, the divergence only started to become increasingly important by the end of the 1990s.

8. Conclusion

We have estimated the rank-size distribution for Swedish cities starting in 1810 until today. We have found some marked deviations from the power law, especially in the beginning of the 19th century when transportation costs were high and therefore market integration was still relatively low.

Sweden is one of the countries with a clear primate city, Stockholm, and this has been the case since the end of the 16th century. In terms of Zipf-consistent population levels, Stockholm has been much larger than predicted by the rank-size relationship for several centuries whereas the subsequent cities at the upper end of the distribution are usually far too small, with the notable exception of Gothenburg by the late 20th century. This marked deviation from the Zipf's law benchmark might even have macroeconomic implications for the Swedish economy, given the tight relationship between population density and productivity and other indicators of economic activity. The dominance of Stockholm at the expense of the other large cities could thus negatively affect the country in terms of economic performance, a hypothesis that deserves further investigation. Last but not least, we have also found some striking evidence against random growth theory, thus potentially explaining the Swedish deviations from the power law benchmark. While we find a slightly negative relationship between city size and subsequent growth rates throughout the 19th century, this relationship reverses throughout the 20th century. Somewhat surprisingly, we find that smaller towns have been growing more rapidly, on average, thus pushing down the Zipf's law coefficient down over the last 100 years. The global tendency towards increasing agglomerations is therefore not as clear-cut in the case of Sweden when using Zipf's law as the benchmark.

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Data

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APPENDIX:

The appendix contains additional information and results from the analysis, including all the regression results for the Zipf's law estimation for each decade as well as the F-test to test whether the coefficient β_2 is equal to unity.

Table 1: OLS regression, Zipf's law all Swedish cities

Based on the following regression: $\ln(S_i) = \beta_1 + \beta_2 \ln(\text{rank}_i) + \varepsilon$

Year	β_1	β_2	F-test $\beta_2 = 1$	Observations	R2
1810	10.59*** (0.07)	-0.97*** (0.02)	0.12	92	0.96
1820	10.82*** (0.11)	-1.01*** (0.03)	0.79	94	0.92
1830	10.99*** (0.12)	-1.03*** (0.03)	0.37	95	0.92
1840	11.05*** (0.09)	-1.02*** (0.02)	0.71	95	0.95
1850	11.26*** (0.07)	-1.04*** (0.02)	0.05	96	0.96
1860	11.5*** (0.09)	-1.05*** (0.02)	0.05	100	0.95
1870	11.82*** (0.09)	-1.09*** (0.02)	0	101	0.95
1880	12.16*** (0.1)	-1.12*** (0.03)	0	101	0.95
1890	12.5*** (0.1)	-1.16*** (0.03)	0	102	0.95
1900	12.73*** (0.11)	-1.17*** (0.03)	0	106	0.93
1910	12.95*** (0.11)	-1.16*** (0.03)	0	118	0.94
1920	13.01*** (0.1)	-1.1*** (0.03)	0	125	0.93
1930	13.07*** (0.11)	-1.08*** (0.03)	0	127	0.93
1940	13.29*** (0.11)	-1.1*** (0.03)	0	130	0.92
1950	13.77*** (0.16)	-1.15*** (0.04)	0	143	0.87
1960	14.07*** (0.17)	-1.2*** (0.04)	0	155	0.84
1970	13.95*** (0.14)	-1.09*** (0.03)	0	159	0.88
1980	13.63*** (0.1)	-0.99*** (0.02)	0.78	159	0.92
1990	13.63*** (0.11)	-0.98*** (0.03)	0.54	160	0.90
2000	13.75*** (0.09)	0.99*** (0.02)	0.14	160	0.93
2010	13.87*** (0.09)	-1.01*** (0.02)	0.11	160	0.93

Source: Author's calculation *,**,*** designate the usual 10%, 5%, and 1% significance level

Table 2:
OLS regression, Zipf's law top 50 Swedish cities
Based on the following regression: $\ln(S_i) = \beta_1 + \beta_2 \ln(\text{rank}_i) + \varepsilon$

Year	β_1	β_2	F-test $\beta_2 = 1$	Observations	R2
1810	10.38*** (0.07)	-0.88*** (0.02)	0	50	0.97
1820	10.48*** (0.08)	-0.88*** (0.03)	0	50	0.96
1830	10.59*** (0.08)	-0.87*** (0.03)	0	50	0.96
1840	10.7*** (0.08)	-0.88*** (0.02)	0	50	0.96
1850	10.93*** (0.07)	-0.91*** (0.02)	0	50	0.97
1860	11.14*** (0.07)	-0.91*** (0.02)	0	50	0.97
1870	11.43*** (0.06)	-0.94*** (0.02)	0.01	50	0.98
1880	11.69*** (0.02)	-0.94*** (0.02)	0.01	50	0.98
1890	11.98*** (0.06)	-0.97*** (0.02)	0.1	50	0.98
1900	12.16*** (0.07)	-0.95*** (0.02)	0.03	50	0.98
1910	12.36*** (0.06)	-0.94*** (0.02)	0	50	0.98
1920	12.55*** (0.06)	-0.94*** (0.02)	0.01	50	0.98
1930	12.63*** (0.07)	-0.93*** (0.03)	0.01	50	0.97
1940	12.84*** (0.07)	-0.95*** (0.02)	0.02	50	0.97
1950	13.03*** (0.08)	-0.91*** (0.02)	0	50	0.97
1960	13.21*** (0.08)	-0.92*** (0.03)	0	50	0.96
1970	13.31*** (0.07)	-0.89*** (0.02)	0	50	0.97
1980	13.27*** (0.07)	-0.88*** (0.02)	0	50	0.97
1990	13.32*** (0.07)	-0.89*** (0.02)	0	50	0.97
2000	13.38*** (0.08)	-0.87*** (0.03)	0	50	0.96
2010	13.5*** (0.08)	-0.89*** (0.03)	0	50	0.96

Source: Author's calculation
*,**,*** designate the usual 10%, 5%, and 1% significance level

Robustness check to the Zipf's law specification

While classically the Zipf's law coefficient is estimated using equation (1), sometimes researchers have adopted the reverse equation where the logarithm of city rank is regressed on the logarithm of city population:

$$(2)\quad \ln(rank_i) = \beta_1 + \beta_2 \ln(S_i) + \varepsilon$$

While the two estimation methods should not lead to fundamentally different results, it is the interpretation of the coefficient that now changes. More specifically, an increase in the coefficient now indicates an increase in the degree of population dispersion in the urban hierarchy instead of a decrease, and vice-versa. Moreover, if Zipf's law strictly holds, then both estimation methods should yield a coefficient that is equal to unity. However, some recent studies point out some flaws with the estimation method given above. More specifically, the OLS estimator for equation (2) is biased downwards for small samples (Gabaix and Ibragimov, 2007). The authors thus propose a remedy to reduce the bias by introducing a shift factor of -1/2 to the city rank data and to estimate the Zipf's law with the following regression:

$$(3)\quad \ln(rank_i - 0.5) = \beta_1 + \beta_2 \ln(S_i) + \varepsilon$$

While we have provided the estimation results of in table 3 and table 4 below, from an analytical point of view we do not obtain fundamentally different results.

Table 3:
OLS regression, Zipf's law all Swedish cities (alternative specification)
Based on the following regression$\ln{(\text{rank}_i - 0.5)} = \beta_1 + \beta_2 \ln{(S_i)} + \varepsilon$

Year	β_1	β_2	F-test $\beta_2 = 1$	Observations	R2
1810	11.09*** (0.16)	-1.06*** (0.02)	0.01	92	0.96
1820	10.56*** (0.22)	-0.97*** (0.03)	0.36	94	0.92
1830	10.43*** (0.22)	-0.94*** (0.03)	0.06	95	0.91
1840	10.87*** (0.18)	-0.99*** (0.02)	0.66	95	0.95
1850	10.95*** (0.16)	-0.98*** (0.02)	0.39	96	0.96
1860	10.96*** (0.18)	-0.96*** (0.02)	0.07	100	0.94
1870	10.85*** (0.17)	-0.92*** (0.02)	0	101	0.95
1880	10.76*** (0.19)	-0.89*** (0.02)	0	101	0.94
1890	10.69*** (0.18)	-0.86*** (0.02)	0	102	0.94
1900	10.76*** (0.19)	-0.84*** (0.02)	0	106	0.93
1910	11.06*** (0.19)	-0.85*** (0.02)	0	118	0.93
1920	11.61*** (0.2)	-0.89*** (0.02)	0	125	0.93
1930	11.84*** (0.2)	-0.9*** (0.02)	0	127	0.93
1940	11.79*** (0.21)	-0.88*** (0.02)	0	130	0.92
1950	11.14*** (0.25)	-0.78*** (0.03)	0	143	0.86
1960	10.75*** (0.24)	-0.73*** (0.03)	0	155	0.84
1970	11.98*** (0.24)	-0.84*** (0.03)	0	159	0.87
1980	13.33*** (0.22)	-0.97*** (0.02)	0.16	159	0.92
1990	13.22*** (0.25)	-0.95*** (0.03)	0.07	160	0.9
2000	13.55*** (0.21)	-0.98*** (0.02)	0.3	160	0.93
2010	13.42*** (0.21)	-0.96*** (0.02)	0.07	160	0.93

Source: Author's calculation
*,**,*** designate the usual 10%, 5%, and 1% significance level

Table 4:
OLS regression, Zipf's law top 50 Swedish cities (alternative specification)
Based on the following regression: $\ln(\text{rank}_i - 1/2) = \beta_1 + \beta_2 \ln(S_i) + \varepsilon$

Year	β_1	β_2	F-test $\beta_2 = 1$	Observations	R2
1810	12.26***	-1.21***	0	50	0.98
	(0.19)	(0.03)			
1820	12.43***	-1.21***	0	50	0.97
	(0.23)	(0.03)			
1830	12.61***	-1.21***	0	50	0.97
	(0.23)	(0.03)			
1840	12.65***	-1.2***	0	50	0.98
	(0.22)	(0.03)			
1850	12.56***	-1.17***	0	50	0.98
	(0.21)	(0.03)			
1860	12.81***	-1.17***	0	50	0.98
	(0.21)	(0.02)			
1870	12.76***	-1.13***	0	50	0.98
	(0.19)	(0.02)			
1880	13.05***	-1.14***	0	50	0.98
	(0.19)	(0.02)			
1890	13.07***	-1.11***	0	50	0.99
	(0.17)	(0.02)			
1900	13.45***	-1.13***	0	50	0.99
	(0.19)	(0.02)			
1910	13.86***	-1.14***	0	50	0.99
	(0.19)	(0.02)			
1920	14.07***	-1.14***	0	50	0.99
	(0.19)	(0.02)			
1930	14.22***	-1.15***	0	50	0.98
	(0.21)	(0.02)			
1940	14.28***	-1.13***	0	50	0.98
	(0.21)	(0.02)			
1950	15.08***	-1.18***	0	50	0.98
	(0.25)	(0.02)			
1960	15.02***	-1.15***	0	50	0.98
	(0.28)	(0.03)			
1970	15.68***	-1.2***	0	50	0.98
	(0.27)	(0.03)			
1980	15.77***	1.21***	0	50	0.98
	(0.27)	(0.03)			
1990	15.63***	-1.19***	0	50	0.98
	(0.27)	(0.03)			
2000	16.04***	-1.22***	0	50	0.98
	(0.29)	(0.03)			
2010	15.9***	-1.19***	0	50	0.98
	(0.28)	(0.03)			

Source: Author's calculation *,**,*** designate the usual 10%, 5%, and 1% significance level

Table 5: Zipf's law median slope estimator (Theil-Sen estimator) for all Swedish cities, including the slope estimator for the 15th, 30th, 50th, 70th, and 85th percentile

Based on the following regression: $\ln(S_i) = \beta_1 + \beta_2 \ln(\text{rank}_i) + \varepsilon$

Year	Percentile	Percentile Slope	Minimum	Maximum
1810	15	-1.50	-1.82	-1.31
n=92	30	-1.19	-1.33	-1.11
	50	-1.05	-1.11	-0.97
	70	-0.90	-0.97	-0.84
	85	-0.80	-0.84	-0.74
1820	15	-1.79	-2.28	-1.51
n=94	30	-1.32	-1.55	-1.18
	50	-1.08	-1.19	-0.99
	70	-0.93	-1.00	-0.84
	85	-0.80	-0.85	-0.73
1830	15	-1.83	-2.37	-1.59
n=95	30	-1.37	-1.64	-1.23
	50	-1.12	-1.24	-1.06
	70	-0.98	-1.06	-0.88
	85	-0.82	-0.89	-0.74
1840	15	-1.79	-2.18	-1.55
n=95	30	-1.38	-1.58	-1.25
	50	-1.13	-1.25	-1.05
	70	-0.99	-1.05	-0.89
	85	-0.83	-0.89	-0.75
1850	15	-1.79	-2.18	-1.56
n=96	30	-1.41	-1.58	-1.30
	50	-1.20	-1.30	-1.09
	70	-1.02	-1.10	-0.91
	85	-0.86	-0.91	-0.76
1860	15	-1.88	-2.54	-1.55
n=100	30	-1.39	-1.60	-1.24
	50	-1.14	-1.23	-1.07
	70	-0.98	-1.06	-0.90
	85	-0.85	-0.89	-0.77
1870	15	-1.94	-2.62	-1.66
n=101	30	-1.45	-1.70	-1.29
	50	-1.21	-1.29	-1.12
	70	-1.03	-1.11	-0.96
	85	-0.90	-0.96	-0.82
1880	15	-2.12	-2.77	-1.77
n=101	30	-1.53	-1.82	-1.36
	50	-1.26	-1.36	-1.16
	70	-1.05	-1.15	-0.96
	85	-0.90	-0.95	-0.81
1890	15	-2.00	-2.52	-1.77
n=102	30	-1.62	-1.81	-1.52
	50	-1.37	-1.52	-1.23
	70	-1.12	-1.22	-1.02
	85	-0.95	-1.02	-0.86
1900	15	-2.26	-2.77	-1.94

n=106	30	-1.70	-1.98	-1.53
	50	-1.34	-1.52	-1.21
	70	-1.11	-1.20	-1.02
	85	-0.94	-1.02	-0.85
1910	15	-2.36	-2.77	-2.07
n=118	30	-1.71	-2.08	-1.49
	50	-1.30	-1.48	-1.16
	70	-1.06	-1.14	-0.99
	85	-0.92	-0.97	-0.84
1920	15	-2.05	-2.66	-1.78
n=125	30	-1.52	-1.78	-1.34
	50	-1.16	-1.31	-1.07
	70	-0.99	-1.05	-0.95
	85	-0.90	-0.94	-0.84
1930	15	-2.09	-2.54	-1.78
n=127	30	-1.47	-1.78	-1.27
	50	-1.12	-1.24	-1.05
	70	-0.97	-1.04	-0.92
	85	-0.88	-0.92	-0.82
1940	15	-2.21	-2.94	-1.78
n=130	30	-1.46	-1.76	-1.25
	50	-1.11	-1.22	-1.04
	70	-0.98	-1.02	-0.93
	85	-0.87	-0.91	-0.81
1950	15	-2.93	-4.02	-2.28
n=143	30	-1.71	-2.21	-1.36
	50	-1.13	-1.30	-1.04
	70	-0.97	-1.02	-0.92
	85	-0.86	-0.90	-0.81
1960	15	-2.96	-4.04	-2.46
n=155	30	-1.86	-2.37	-1.53
	50	-1.25	-1.44	-1.11
	70	-1.00	-1.07	-0.95
	85	-0.88	-0.93	-0.82
1970	15	-2.58	-3.29	-2.09
n=159	30	-1.61	-2.00	-1.35
	50	-1.11	-1.27	-1.01
	70	-0.93	-0.98	-0.89
	85	-0.85	-0.88	-0.81
1980	15	-1.89	-2.49	-1.56
n=159	30	-1.29	-1.52	-1.14
	50	-1.01	-1.09	-0.95
	70	-0.88	-0.92	-0.85
	85	-0.81	-0.84	-0.77
1990	15	-1.66	-2.19	-1.44
n=160	30	-1.21	-1.40	-1.09
	50	-0.98	-1.04	-0.93
	70	-0.88	-0.91	-0.85
	85	-0.80	-0.83	-0.76
2000	15	-1.79	-2.32	-1.51

n=160	30	-1.25	-1.45	-1.13
	50	-1.02	-1.09	-0.97
	70	-0.91	-0.94	-0.88
	85	-0.84	-0.87	-0.80
2010	15	-1.79	-2.45	-1.48
n=160	30	-1.22	-1.43	-1.10
	50	-1.01	-1.06	-0.97
	70	-0.92	-0.95	-0.89
	85	-0.85	-0.88	-0.81

Source: Author's calculation *,**,*** designate the usual 10%, 5%, and 1% significance level

Table 6:
Zipf's law median slope estimator (Theil-Sen estimator), top 50 Swedish cities
Based on the following regression: $\ln(S_i) = \beta_1 + \beta_2 \ln(\text{rank}_i) + \varepsilon$

Year	Percentile	Percentile Slope	Minimum	Maximum
1810	50	-0.84	-0.91	-0.80
1820	50	-0.84	-0.92	-0.79
1830	50	-0.86	-0.98	-0.80
1840	50	-0.88	-1.00	-0.81
1850	50	-0.92	-1.05	-0.84
1860	50	-0.92	-1.06	-0.84
1870	50	-0.93	-1.02	-0.86
1880	50	-0.92	-1.01	-0.83
1890	50	-0.94	-1.02	-0.88
1900	50	-0.92	-1.02	-0.86
1910	50	-0.92	-0.99	-0.86
1920	50	-0.91	-0.97	-0.83
1930	50	-0.84	-0.90	-0.79
1940	50	-0.84	-0.93	-0.79
1950	50	-0.80	-0.85	-0.76
1960	50	-0.80	-0.87	-0.75
1970	50	-0.83	-0.88	-0.77
1980	50	-0.84	-0.89	-0.77
1990	50	-0.86	-0.90	-0.78
2000	50	-0.82	-0.88	-0.76
2010	50	-0.83	-0.88	-0.77

Source: Author's calculation *,**,*** designate the usual 10%, 5%, and 1% significance level

Table 7:
Power law test for the top 50 Swedish cities based on Gabaix (2009a)

Year	n	β_2	β_3	(β_3/β_2^2)	1.95(2n)^-5	Reject
1810	50	-1.573***	0.037**	0.015	0.195	NO
1820	50	-1.620***	0.040**	0.015	0.195	NO
1830	50	-1.573***	0.034*	0.014	0.195	NO
1840	50	-1.343***	0.013	0.007	0.195	NO
1850	50	-0.993***	-0.019	-0.019	0.195	NO
1860	50	-1.056***	-0.012	-0.011	0.195	NO
1870	50	-0.969***	-0.019	-0.020	0.195	NO
1880	50	-0.933***	-0.022	-0.026	0.195	NO
1890	50	-1.123***	0.001	0.001	0.195	NO
1900	50	-1.221***	0.010	0.001	0.195	NO
1910	50	-1.252***	0.011	0.007	0.195	NO
1920	50	-1.426***	0.028**	0.007	0.195	NO
1930	50	-1.744***	0.057***	0.014	0.195	NO
1940	50	-1.578***	0.044***	0.019	0.195	NO
1950	50	-2.140***	0.079***	0.018	0.195	NO
1960	50	-2.031***	0.075***	0.017	0.195	NO
1970	50	-1.996***	0.060***	0.015	0.195	NO
1980	50	-1.999***	0.059***	0.015	0.195	NO
1990	50	-1.826***	0.048***	0.015	0.195	NO
2000	50	-2.209***	0.070***	0.014	0.195	NO
2010	50	-2.081***	0.066***	0.015	0.195	NO

Source: Author's calculation *,**,*** designate the usual 10%, 5%, and 1% significance level

Table 8:
Top 10 Swedish cities by population:

	City Rank									
Year	1	2	3	4	5	6	7	8	9	10
1810	Stockholm	Göteborg	Karlskrona	Norrköping	Malmö	Gävle	Falun	Kalmar	Uppsala	Visby
1820	Stockholm	Göteborg	Karlskrona	Norrköping	Gävle	Malmö	Kalmar	Uppsala	Falun	Visby
1830	Stockholm	Göteborg	Karlskrona	Norrköping	Malmö	Gävle	Kalmar	Uppsala	Kristianstad	Jönköping
1840	Stockholm	Göteborg	Norrköping	Karlskrona	Malmö	Gävle	Kalmar	Lund	Uppsala	Linköping
1850	Stockholm	Göteborg	Norrköping	Karlskrona	Malmö	Gävle	Uppsala	Lund	Kalmar	Jönköping
1860	Stockholm	Göteborg	Norrköping	Malmö	Karlskrona	Gävle	Uppsala	Lund	Kalmar	Jönköping
1870	Stockholm	Göteborg	Malmö	Norrköping	Karlskrona	Gävle	Uppsala	Jönköping	Lund	Kalmar
1880	Stockholm	Göteborg	Malmö	Norrköping	Gävle	Karlskrona	Jönköping	Uppsala	Lund	Örebro
1890	Stockholm	Göteborg	Malmö	Norrköping	Gävle	Uppsala	Karlskrona	Helsingsborg	Jönköping	Lund
1900	Stockholm	Göteborg	Malmö	Norrköping	Gävle	Helsingsborg	Karlskrona	Jönköping	Uppsala	Örebro
1910	Stockholm	Göteborg	Malmö	Norrköping	Gävle	Helsingsborg	Örebro	Eskilstuna	Karlskrona	Jönköping
1920	Stockholm	Göteborg	Malmö	Norrköping	Helsingsborg	Gävle	Örebro	Västerås	Eskilstuna	Jönköping
1930	Stockholm	Göteborg	Malmö	Norrköping	Helsingsborg	Gävle	Borås	Örebro	Eskilstuna	Jönköping
1940	Stockholm	Göteborg	Malmö	Norrköping	Helsingsborg	Örebro	Borås	Eskilstuna	Gävle	Västerås
1950	Stockholm	Göteborg	Malmö	Norrköping	Helsingsborg	Örebro	Uppsala	Västerås	Borås	Linköping
1960	Stockholm	Göteborg	Malmö	Norrköping	Uppsala	Västerås	Helsingsborg	Örebro	Borås	Jönköping
1970	Stockholm	Göteborg	Malmö	Uppsala	Västerås	Norrköping	Örebro	Helsingsborg	Jönköping	Linköping
1980	Stockholm	Göteborg	Malmö	Uppsala	Västerås	Norrköping	Örebro	Linköping	Helsingsborg	Jönköping
1990	Stockholm	Göteborg	Malmö	Uppsala	Västerås	Norrköping	Örebro	Helsingsborg	Linköping	Jönköping
2000	Stockholm	Göteborg	Malmö	Uppsala	Västerås	Örebro	Linköping	Helsingsborg	Norrköping	Jönköping
2010	Stockholm	Göteborg	Malmö	Uppsala	Västerås	Örebro	Linköping	Helsingsborg	Jönköping	Norrköping

Source: CyberCity, Folknet database, SCB, author's calculations

Table 9: Zipf's law consistent population for Top 10 Swedish cities

The ratio corresponds to S_i/S_i^z where S_i^z is the "Zipf-consistent population" (predicted population) computed from the OLS estimator based on the restricted sample of 50 cities and S_i is the actual population

	City Rank									
Year	1	2	3	4	5	6	7	8	9	10
1810	2.04	0.82	0.88	0.96	0.75	0.84	0.74	0.83	0.89	0.85
1820	2.12	0.85	0.85	0.92	0.81	0.91	0.74	0.77	0.77	0.79
1830	2.02	0.97	0.77	0.85	0.89	0.93	0.74	0.7	0.77	0.79
1840	1.89	0.89	0.76	0.95	0.95	0.89	0.75	0.74	0.81	0.82
1850	1.67	0.88	0.82	0.89	1.02	0.85	0.73	0.8	0.88	0.88
1860	1.64	1.01	0.79	0.97	0.96	0.82	0.72	0.81	0.87	0.88
1870	1.48	1.18	0.78	0.96	0.82	0.81	0.78	0.84	0.92	0.88
1880	1.41	1.23	0.9	0.83	0.72	0.83	0.85	0.93	0.95	0.87
1890	1.55	1.28	0.88	0.79	0.7	0.76	0.85	0.95	1.03	0.87
1900	1.58	1.33	0.91	0.81	0.72	0.71	0.8	0.88	0.97	1.03
1910	1.46	1.38	1	0.73	0.68	0.77	0.8	0.86	0.93	1
1920	1.48	1.37	1.13	0.76	0.76	0.72	0.79	0.77	0.85	0.9
1930	1.63	1.51	1.09	0.73	0.82	0.67	0.76	0.85	0.83	0.86
1940	1.57	1.44	1.16	0.7	0.76	0.71	0.81	0.77	0.84	0.91
1950	1.79	1.46	1.14	0.66	0.68	0.75	0.81	0.87	0.93	0.97
1960	1.76	1.54	1.15	0.59	0.63	0.74	0.84	0.94	0.92	1.02
1970	1.6	1.48	1.16	0.56	0.69	0.78	0.84	0.87	0.94	1
1980	1.7	1.45	1.03	0.6	0.7	0.76	0.8	0.85	0.93	1
1990	1.71	1.42	0.98	0.63	0.68	0.73	0.79	0.86	0.9	0.98
2000	1.88	1.41	1.01	0.65	0.65	0.72	0.8	0.84	0.87	0.94
2010	1.88	1.39	1.02	0.66	0.63	0.72	0.8	0.84	0.86	0.92

Source: Author's calculation

Table 10:
Rank autocorrelation for all Swedish cities, based on 40-year intervals

Year	Rank autocorrelation to 40 years earlier	n
1840	94.3%	81
1850	94.3%	92
1860	95.2%	94
1870	93.6%	95
1880	90.7%	95
1890	89.5%	96
1900	89.1%	100
1910	88.5%	101
1920	89.1%	101
1930	90.3%	102
1940	92.1%	106
1950	87.5%	118
1960	89.5%	120
1970	87.7%	121
1980	87.7%	124
1990	83.2%	137
2000	83.7%	155
2010	89.3%	159

Source: Author's calculation

Growth, Factor Shares, and Factor Prices

I am an economist and economic historian. For the last few years, I have worked on my PhD thesis at the Economic History Department at Lund University. I am currently employed for a research PhD internship by the European Central Bank.

My dissertation focuses on the economics of growth, income inequality, factor shares, and factor prices. While my thesis is not about secular stagnation per se, the attentive reader will notice that all four of my papers discuss Larry Summer's theory in one way or the other. I have also been teaching a Master course at the Department on Economic Growth and was involved in the supervision of Bachelor and Master theses.

Besides my formal academic work, I have written several pieces for The Conversation. These articles were reproduced by the BBC, Bloomberg Quint, and some other media outlets and have generated a resadership of some 200.000+.

I have also frequently been writing on my blog on topics that are dear to my heart, ewith a special focus on monetary economics and monetary theory, macroeconomics, and economic history, too.

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