LUND UNIVERSITY

The Dynamics of Swedish House Prices in the 20th and 21st Century

A cointegration analysis of the relationship between house prices and the real macroeconomy throughout Sweden's modern history.

Theo Herold
Master's Thesis
Supervisor: Fredrik NG Andersson
Lund University School of Economics and Management
Department of Economics
2021

Abstract: Using data spanning from 1910 to 2020, house price dynamics of Stockholm and Gothenburg are found to be significantly affected by income, household debt, interest rates, construction costs and immigration. Real house prices in Stockholm and Gothenburg exhibit debt elasticities of 1.34 and 1.12, noticeably greater than their respective income elasticities of 0.24 and 0.39. Real house prices in both cities take around 10 years to adjust towards equilibrium, which is inherently more sluggish than for other industrialized countries found in the literature. Between 1910 to 1980, house price cycles have driven credit cycles, which have since then become mutually reinforcing in Gothenburg and exclusively running from real debt to real house prices in Stockholm.

Key words: house prices, housing market, Sweden, cointegration, VECM

Contents

1. Introduction[1]

Buying a house is the single biggest investment a given household can do over its lifespan. As households have to account for income, access to credit and the interest rate environment, the sole magnitude of such a purchase implies that house prices are closely tied to the macroeconomy (see for instance Englund & Ioannides, 1997; Holly & Jones, 1997; Oikarinen, 2009; Kepili, 2020). Indeed, income and credit[2] directly affect housing affordability, and the interest rate environment dictates the mortgage rate that households face. Similarly, other variables such as construction and demographics should at least in part explain fluctuations in house prices. Since the beginning of the 19th century real house prices in Sweden have been strikingly volatile with a standard deviation almost double than that of both real goods and real income.[3] Despite its volatility, real Swedish house prices were almost 40 percent lower in beginning of the 1990's than in the 1880's.

While the empirical literature is vast with support for using fundamental macroeconomic variables to explain fluctuations in house prices (see for instance Englund & Ioannides, 1997; Holly & Jones, 1997; Egert & Mihaljek, 2007; Muellbauer & Murphy, 2008), the role of real debt and credit accessibility has been increasingly more examined and found to exhibit predictive prowess of house price dynamics (see for instance Hofmann, 2003; 2004; Brissimis & Vlassopoulos, 2008; Oikarinen, 2009; Kepili, 2020). By and large, the analysis into house price dynamics within economics is scarce prior to the 1960's, in large part due to shortage of data. The case of Sweden is no different. There is a clear gap in the understanding of the long- and short-run relationship of house prices in Sweden.

The aim of this thesis is to remedy this shortcoming by analyzing the long- and short-run dynamics of house prices and the Swedish macroeconomy through a vector error-correction model (VECM). The macroeconomy is modelled with real income, real debt and the real interest rate, the supply side of housing is captured through real construction costs and demographics captured through total immigration. This is done for the period between 1910 to 2020 for Sweden's two largest cities, Stockholm and Gothenburg. The house price indices

---

[1] I would like to extend my sincerest gratitude to Klas Eriksson (Stockholm University and Research Institute Ratio) and Fredrik NG Andersson (Lund University) for guidance and feedback. I furthermore thank Rodney Edvinsson (Stockholm University) and Lars Ahnland (Stockholm University) for providing me with comments and data without which this thesis would not be possible.

[2] "Real debt" and "real total private debt", as well as "debt" vis-à-vis "credit", are used interchangeably throughout.

[3] The logarithmic rate of change of real house prices over the sample period 1818-2020 has a standard deviation of 0.1, whereas the logarithmic rate of change of both the consumer price index and real income are 0.06 and 0.04, respectively.

come from Söderberg et al. (2014), Bohlin (2014) and Edvinsson et al. (2020) while the macroeconomic variables primarily come from Ahnland (2015), Edvinsson (2013a, 2013b, 2014), the Swedish Riksbank and SCB. Complementary statistics come from SCB and the Riksbank.

A statistically significant and stable long-run relationship between the variables is found. Real house prices in Stockholm and Gothenburg exhibit debt elasticities of 1.34 and 1.12, and income elasticities of 0.24 and 0.39. This is noticeably different to other findings in the literature, both for Sweden and for other industrialized countries, where the coefficient of real income tends to be higher than that of real debt (see for instance Hofmann, 2004; Oikarinen, 2009; Berki & Szendrei, 2017). Real house prices in both cities adjust sluggishly towards long-run equilibrium – possibly the result of extensive regulation throughout the majority of the 20th century. This is noticeably slower than for other industrialized countries found in the literature (see for instance Holly & Jones, 1997; Egert & Mihaljek, 2007; Kishor & Marfatia, 2017). The period after 1980 marks a shift in the short-run dynamics from the period between 1910 and 1980. House price cycles drove credit cycles throughout the majority of the 20th century, while the relationship since the 1980's has become mutually reinforcing in Gothenburg and exclusively running from real debt to real house prices in Stockholm. The result suggests that real house prices in 2020 are 2.5 times higher than what the underlying fundamentals would indicate.

The disposition is as follows: In chapter 2, I give an historical overview of relevant events from the later parts of the 19th century up until 2020. In chapter 3, I go over related literature within economics and economic history. In chapter 4, I discuss related economic theory and the chosen variables. In chapter 5, I present the data, its sources and how complementary data was used. In chapter 6, I present the econometric model and its specifications, and form hypotheses around the expected results. Chapter 7 contains the analysis of house prices in Stockholm and Gothenburg between 1910 and 2020, their long- and short-run dynamics and causal direction. Chapter 8 discusses the results in depth and shows the historic development of real house prices against the predicted cointegrated equation throughout the 20th and 21st century. In Chapter 9 I give some concluding remarks, including venues for further research.

2. Historical Context

The end of the 19th century saw Sweden emerge as an industrialized society, and with it came a sophistication of housing-, asset- and other financial markets. The Stockholm stock exchange was formed in 1863 and the Riksbank was established as the de facto central bank in 1897 (Waldenström, 2014; Andersson, 2020). Between the mid-1890's to 1906 the number of commercial banks almost doubled and market capitalization to GDP – often considered a measurement of financial development[4] – tripled (Ahnland, 2015). The increase in welfare and development had its spillover onto asset markets as real house prices in Stockholm doubled and real stock prices almost tripled between 1870 to 1900 (Söderberg et al, 2014; Waldenström, 2014).

The early 20th century saw an early financial crisis in 1907, originating from the United States and culminating in a steep decline in construction following serial striking and lockouts in Stockholm (Söderberg et. al, 2014). Soon thereafter, in 1914, Sweden experienced a 20 percent decline in growth, and real estate construction came to a standstill – largely the result of the first world war (Edvinsson & Hegelund, 2016). In 1917 national rent control was introduced (Söderberg et al., 2014).[5] A deflation crisis affecting much of the industrialized world hit Sweden especially hard and resulted in a decrease in GDP of almost 30 percent in the early 1920's (Edvinsson & Hegelund, 2016). The period between 1920 to 1930 was politically tumultuous. The liberal government of Nils Edén resigned in 1920, following the issue of Swedish membership in the League of Nations, and Social Democrat Hjalmar Branting formed a temporary cabinet. What followed was a half a century long monopoly of political power by the Social Democratic Party up until 1973. This marked the emergence of the Swedish welfare state and a growing public sector, with government expenditure and debt-to-GDP growing annually by 3.5 and 3 percent respectively between 1920 to 1985 (Fregert & Svensson, 2014). Under the Social Democratic party between 1940 to 1970, real house prices were largely stagnant, in part due to the extensive emphasis on housing market regulation.

The 1930's commenced under economic decline due to the Great Depression. The Saltsjöbaden deal in 1931 between the labor union LO and the employer's organization SAF stipulated the future of Swedish labor policy, but also increased emphasis on public ownership of real estate by increasing the degree of subsidization to building cooperatives

[4] See for instance Rajan & Zingales (1998).
[5] And still remain to this day, albeit in a slightly different form.

such as HSB and Riksbyggen (Eriksson, 2021). Compulsory auctions rose in 1932, contributing to an average decline in property prices between 1931 to 1942 (Söderberg et al., 2014). In 1939, foreign exchange controls were imposed which disallowed the sale of the Swedish krona over the border. 1942 saw the reintroduction of rent control, that had been on hiatus since 1923, while the "Planning and Building law" in 1947 started regulating the usage of land and building activity in Sweden. Exploitation of private property now needed permission from the city of which buildings could be built and where (Eriksson, 2021). Capital controls were introduced in 1951 which allowed the Riksbank to control commercial bank's interest rates and lending decisions (Andersson, 2020).

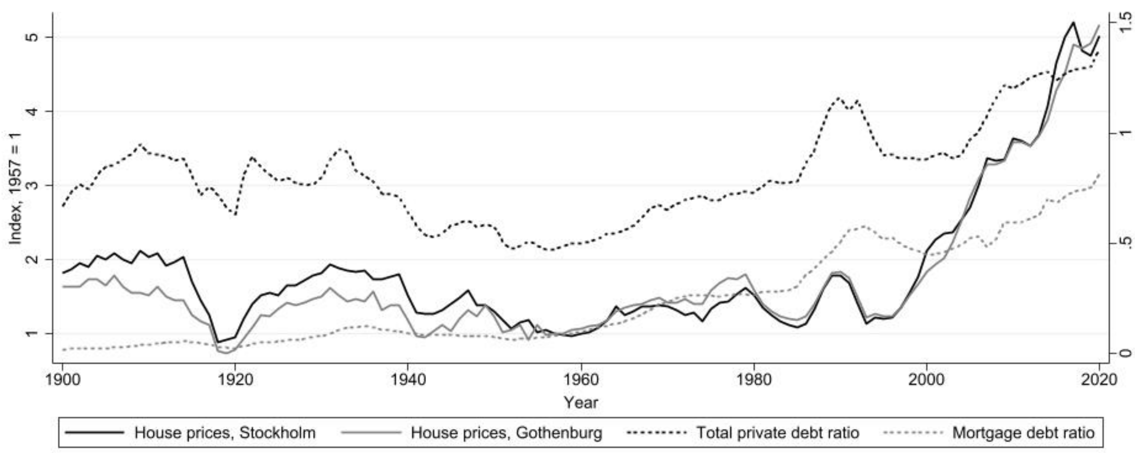
"Miljonprogrammet" – roughly the "Million Programme" – was introduced in 1965 and aimed to build accessible standardized housing for the population. Over a 100 000 apartments and houses were built annually over a ten year period and a considerable part of the old housing stock was demolished leading to a fall in prices for apartment buildings (Edvinsson et al., 2020). Regulation of the demand side of credit in 1962 commanded investors to place a fraction of their assets in treasuries and housing bonds, and also introduced credit ceilings, penalty fees and cash ratios (Ahnland, 2015). Increased government spending, partly due to the growing public sector and partly due to expansionary fiscal policy following the oil crises of the 1970's, saw public debt-to-GDP rise from around 15 to 60 percent between 1973 to 1985. The Social Democratic hegemony was shattered following the election defeat in 1976 and a more unified opposition of liberal and conservative parties emerged.

The 1980's and 1990's saw two major shifts on Swedish credit-, asset- and housing markets: the deregulation of financial markets, with its subsequent equitization of housing, and the "Tax Reform of the Century". The global trend of financial market liberalization reached Sweden in the 1980's which led to the abolishing of credit and foreign exchange controls. Major financial market reform in the way of credit and currency deregulation happened in the mid-1980's (Waldenström, 2014). However, the Social Democratic government had already appointed a special committee in 1980 to investigate potential deregulation, and the Swedish Riksbank had itself started emitting treasury bonds for the first time in 1980 (Broberg, 2014). Household solvency increased due to lower mortgage transactions costs, the establishing of secondary mortgage markets, the removal of credit ceilings as well as an increased ability to extract equity from owner-occupied housing (Gerardi et al., 2010). A few years later, under the center-right government, the largest tax reform in Swedish history was passed in 1990-1991. The effective tax rate was lowered but the taxable base was widened, by for instance slashing both the income tax and overall government expenditure but introducing a property tax and new value-added taxes (Englund, 2019). Both reforms increased household income and access to credit, which created upwards inflationary pressure on house prices.

This property boom culminated in the banking crisis and later the currency crisis of 1991-1994, resulting in the merging of several commercial banks, a further increase in government spending and the abolishing of the fixed exchange rate of the Swedish krona (Ahnland, 2015). Although house prices and debt levels temporarily subdued following the crisis, unprecedented global increases in both led to the international financial crisis of 2008. Governments around the world responded by conducting debt-financed deficit spending in historical proportions. These expansionary fiscal policies led to surging levels of public debt specifically in a range of Southern European countries and triggered the European debt crisis of 2012. As a relatively small, exporting economy in the European Union, this had an effect on Sweden as well. By 2015, the Riksbank lowered their policy rate to negative levels for the first time - which remained in place until late 2019.

Today the issue of rent regulation continues to lie at the heart of the economic debate in Sweden (see for instance Andersson & Söderberg, 2012; Lindbeck, 2016; Herold, 2019; Kopsch, 2019, 2021). While regulatory reforms such as mortgage lending controls and amortization requirements followed the global financial crisis, private indebtedness and house prices continue to rise. Since 2010 house prices have risen by roughly 50 and 60 percent in Stockholm and Gothenburg respectively. The increase in house prices in both nominal and real terms is historically unprecedented.

Figure 1. Real house prices (left axis), 1957=1, and real aggregate private debt- and real aggregate mortgage debt-to-GDP (right axis), percent. 1900-2020.



Source: Söderberg et al. (2014), Bohlin (2014), Ahnland, (2015) and Edvinsson (2020). Complementary data from SCB – see appendix A1.

3. Previous Research

Real income, real debt and real interest rates have empirically been shown to carry explanatory power of developments in house prices. Englund and Ioannides (1997) find significant predictive power of the real interest rate and real GDP growth in 15 OECD economies. Looking at the UK between 1939 to 1994, Holly & Jones (1997) find real income to be the most important explanatory variable and show that real house prices have risen in line with real income almost interchangeably over the last 60 years. Egert & Mihaljek (2007) find that real interest rates, household income and housing credit are strong predictors of house prices in 19 OECD countries. Examining the UK between 1972 to 2003, Muellbauer & Murphy (2008) show that real income, real interest rates, availability of credit, expected appreciation and demography are fundamental drivers. Kishor & Marfatia (2016) find significant results between real house prices, real interest rates and real income, and a significant heterogeneity in synchronization of house price fluctuations between 15 OECD countries.

Financial- and housing market development has been extensively studied following the financial crisis. Egert & Mihaljek (2007) find strong evidence of institutional development of housing markets to carry explanatory power on top of underlying fundamentals on house price dynamics. Analyzing 19 industrialized countries, Calza et al (2013) show that the impact of policy on residential investment and house prices is stronger in countries with more flexible mortgage markets. Ahamada & Sanchez (2013) find that the effect of house price shocks on real consumption and real GDP increased after the financial market deregulations of the 1980's in the United States, signaling a strengthening of house prices on the macroeconomy. Examining 20 OECD countries between 1970 to 2015, Agnello et al. (2019) show that more liberalized mortgage markets are associated with longer housing booms whereas increased securitization yields shorter housing busts. Looking at Malaysia between 1999 to 2012, Kepili (2020) finds that increased market liberalization increases prices for every type of housing with apartment buildings showcasing the largest increase in prices.

The causal direction between the house prices and credit continues to be disputed however. Looking at 20 countries, Hofmann (2003) finds long-run causality running from property prices to bank lending, suggesting that property price cycles drive credit cycles. This is further reinforced in Brissimis & Vlassopoulos (2008) who find no long run causation from mortgage lending to house prices in Greece. On the contrary, Hofmann (2004) and Goodhart & Hofmann (2007) find a mutually reinforcing relationship between private sector credit and real house prices when analyzing 16 and 17 industrialized countries respectively. Similar results are found in Fitzpatrcik & McQuinn (2004) and Oikarinen (2009) between bank lending and house prices in Finland and Ireland respectively.

The house price cycle behavior with booms and busts has seen rigorous analysis the past decade. Looking at the US between 1960 to 2011, Nneji et al. (2013) show that booms and busts affect the underlying relationship between house prices and macroeconomic variables. While Englund and Ioannides (1997) find evidence of interdependency between house price dynamics between 15 OECD countries, the authors find no econometric evidence to support the existence of an international house price cycle. On the contrary, Kishor & Marfatia (2016) find significant heterogeneity in synchronization in house price fluctuations between 15 OECD countries. Cesa-Bianchi (2013) similarly finds significant spillover in housing markets for advanced economies, but finds no such effect from advanced economies to developing economies.

The research into the historical context and development of Swedish house prices is manifold (see for instance Jacobsson, 1996; Lind & Lundström, 2011; Edvinsson et al., 2020; Eriksson, 2021). Edvinsson et al. (2020) propose that long-term trends in Swedish house prices between 1818 to 2018 are closely linked to institutional change. Periods of regulation are followed by stagnating real house prices and decreased wealth-to-income ratios, whereas periods of deregulation see rising real house prices, increasing capital gains and rising household debt. More recently, Eriksson (2021) analyzes how private and public real estate ownership has related to each other historically and finds that regulation of private interests in relation to public interests has increased over time. The 20th century in particular saw the emergence of “functional socialism”, where the formal ownership of real estate, although still in the hands of the private sector, shifted practical ownership to the public through extensive regulation.

This thesis brings many new contributions to the current literature. Few researchers go beyond the 1960-1970’s for econometric analysis of the long- and short-run dynamics of house prices and the macroeconomy - partly due to a lack of data and partly due to frequency mismatches in the available data.[6] The literature into house price dynamics in multiple cities in the same country over extended periods of time is also limited. To the best of my knowledge, this paper is the first to econometrically analyze the long- and short-run dynamics

[6] There are some obvious exceptions, such as Holly & Jones (1997). The authors analyze house price dynamics in the UK between 1939 to 1994.

of house prices within these parameters in Sweden for over the majority of the 20th century, all the way up until the present.

4. Theory

Many theoretical models explore the important linkages of house prices, real economic activity and private credit (see for instance Poterba, 1984; Miles, 1992; Kiyotaki & Moore, 1997; Meen, 2001; Iacoviello, 2005; Iacoviello & Neri, 2010). The "asset market approach" of owner-occupied housing stipulates that the price of a house should equal the discounted value of future housing service flows[7] (Poterba, 1984; Meen, 2001). These housing services depend on the real rental price of the services and individuals will consume these services until their marginal value equals their cost. It follows that the price of a property, which comes with a range of expenses for the owner, will be reflected in the *hypothetical* rent. After all, there is little point in owning a dwelling if costs exceed any future returns on ownership, in where renting the dwelling to possible tenants can play a major role.

In long-run equilibrium, the annual cost of ownership $\boldsymbol{P_t}$ must equal the annual cost of renting $\boldsymbol{R_t}$, modelled as

$$\boldsymbol{R_t} = \boldsymbol{P_t U_t} \qquad (1)$$

where $\boldsymbol{U_t}$ is the *user cost of capital*. $\boldsymbol{U_t}$ should be viewed as the opportunity cost of investing in an alternative asset and takes into account the risk free real interest rate $\boldsymbol{r_t^{rf}}$ of the alternative asset, property tax $\boldsymbol{\tau_t^{property}}$ and tax benefits for some effective tax rate $\boldsymbol{\tau_t}$ from which mortgage interest $\boldsymbol{r_t^{mortgage}}$ and property taxes $\boldsymbol{\tau_t^{property}}$ are assumed to be deductible, the depreciation rate $\boldsymbol{\delta_t}$, a risk premium $\boldsymbol{\gamma}$, and future returns of house ownership $\boldsymbol{\xi_{t+1}}$ over $t = 1, 2 \ldots T$ periods. The cost of ownership can be written as

$$\boldsymbol{P_t U_t} = \boldsymbol{P_t r_t^{rf}} + \boldsymbol{P_t \tau_t^{property}} - \boldsymbol{P_t \tau_t} \left(\boldsymbol{r_t^{mortgage}} + \boldsymbol{\tau_t^{property}}\right) + \boldsymbol{P_t}(\boldsymbol{\gamma} + \boldsymbol{\delta_t} - \boldsymbol{\xi_{t+1}}) \quad (2)$$

In the case of Sweden, tax deductibility of mortgage interest payments carries certain requirements of the household. For instance, households must have paid taxes from which the deductibility can be drawn and made successful amortizations in previous years. Furthermore, there is no formal property tax, rather a "property tithe" which is collected by

[7] As Poterba (1984) describes it, "housing services" are defined as "after-tax depreciation, repair costs, property taxes, mortgage interest payments, and the opportunity cost of housing equity, minus the capital gain on the housing structure".

the municipality. The property tithe does not entitle tax deductibility and, as it is not formally considered a tax, we assume the tithe to be included in the rate of depreciation. With these assumptions, (1) and (2) can be rewritten as

$$\boldsymbol{R_t} = \boldsymbol{P_t U_t} = \boldsymbol{P_t}(\boldsymbol{r_t^{rf}} + \boldsymbol{\gamma} + \boldsymbol{\delta_t} - \boldsymbol{\tau_t r_t^{mortgage}} - \boldsymbol{\xi_{t+1}}) \quad (3)$$

The price of owner-occupied housing is positively related to the risk free real interest rate $\boldsymbol{r_t^{rf}}$**,** the risk premium $\boldsymbol{\gamma}$ and the rate of depreciation $\boldsymbol{\delta_t}$, and negatively related to the effective tax rate $\boldsymbol{\tau_t}$ (after potential mortgage deductions $\boldsymbol{r_t^{mortgage}}$) and future expected return of owning the house $\boldsymbol{\xi_{t+1}}$**.** Assuming constant rents and a constant housing stock, any move away from the equilibrium condition $\boldsymbol{R_t} = \boldsymbol{P_t U_t}$ by a fall in user costs must be offset by increasing house prices and vice versa.

Within this framework, changes in inflation gives rise to two different effects. An increase in inflation will reduce user costs as the tax subsidy increases and capital gains reduces the effective cost of home ownership (Poterba, 1984). The intuition is that increased inflation lead to increases in tax deductible nominal mortgage interest payments $\boldsymbol{r_t^{mortgage}}$, and capital gains $\boldsymbol{\xi_{t+1}}$ - which are untaxed - rise in nominal terms due to house appreciation. Because of this, increases in inflation lead to higher house prices. On the other hand, increased inflation raises the nominal interest rate and thus implies that annuity repayment on mortgage debt increases in the starting years of indebtedness. This implies increased credit constraints, which suppresses the demand for housing. The overall effect of inflation is dependent on whether the fall in user cost is greater than the rise in annual annuity repayments.

In the similar present value model, the price of housing equals the discounted value of net housing services of the housing stock. In equilibrium, the real price of houses $\boldsymbol{P_t^H / P_t}$ is equal to the real price of household services $\boldsymbol{s_t}$ divided by the user cost $\boldsymbol{U_t}$ over $t = 1, 2 \ldots T$ periods. The present value model is generally extended in the literature into an asset price formula where the price-to-rent ratio of housing reflects households' *expectations* about future increases in rent and returns on owner-occupied housing. Empirically, past growth patterns tend to be used to explain expected rent and price growth, turning forward-looking behavior into backwards-looking behavior and defeating the purpose of the theoretical framework in the process.

The estimated empirical model that best follows the theoretical underpinning above features determinants of the demand of housing services (Holly & Jones, 1997). This would imply the usage of income, private credit, interest rates, supply side variables and demographic factors. How should then the included variables affect house prices?

As we have seen, empirical evidence largely suggest that increased income is tied to rising house prices. The intuition is straight forward: higher income leads to increased wealth and thereby an increased affordability of housing and rising house prices. In the extreme case where a household is uninterested in consumption smoothing, income will be without an effect on house prices and should carry no effect on house prices in the long-run, ceteris paribus.

The existence of household debt is taken as a given within the asset market approach – the representative household has to borrow in order to buy a house. Credit aggregates capture the financing cost of housing and contain information about house price and income expectations. Increased house price or income uncertainty means that precautionary savings increase which induces households to borrow less. However, increases in perceived future income should lead to a willingness to smooth consumption over time and thus increase borrowing. In any case, household debt is expected to positively correlate with house prices in the long run as mortgage debt is accumulated with the purpose of acquiring housing.

The cost of ownership is heavily dependent on the interest rate environment but the effect is ambiguous. Expansive monetary policy reduces mortgage interest $\boldsymbol{r_t^{mortgage}}$ and the risk free interest rate $\boldsymbol{r_t^{rf}}$ on the alternative asset. Thus, lower interest rates lead to increased incentives to invest in housing, increased indebtedness and thus rising house prices. On the other hand, contractionary monetary policy could indicate expected future growth and higher returns on asset-holding. This implies either a negative or positive correlation depending on the dominating effect. A seeming majority finds interest rates to negatively correlate with house prices (Egert & Mihaljek, 2007; Muellbauer & Murphy, 2008; Hofmann, 2003; Oikarinen, 2009).

The housing stock should be negatively correlated with house prices in the long run. In the short term, the housing stock could be increasing in line with increasing demand for housing, leading to supply and demand moving together. As more houses are built and supply increases, prices will eventually move in the opposite direction until supply equals demand.

Total immigration is used as the “demographic variable”. Immigration prior to 1940 was relatively modest but has since then steadily increased. Theoretically, this flow of persons implies an increased demand for housing and housing services which should drive prices upwards. Tumbarello & Wang (2010) find that a percentage increase in net migration constitutes a 0.06 percent increase in house prices. While immigration should carry little significance in explaining Swedish house prices prior to the 1940's, there is reason to believe that the relationship has grown stronger over time throughout the 20th century.

5. Data

While the asset-market model does provide a good framework for which underlying variables might affect house prices in a theoretical sense, creating an empirical model following the same rationale is not straight forward. Holly & Jones (1997) proxy the unobservable real rental price of housing services on the determinants of housing services, income, demographic factors and supply side factors. In fact, a vast majority of the literature draws upon the asset market approach but utilizes proxies and more crude estimations of more elusive variables. It is also important to account for what the research question is: when analyzing the dynamics of debt and house prices, Hofmann (2004), Goodhart & Hofmann (2007) and Oikarinen (2009) omit supply side- and demographic factors altogether, and instead use theoretically motivated variables analyzed through recursive ordering.

The data used is in annual frequency and stretches at the longest from 1910 to 2020. The data is gathered from a wide range of different papers and databases, each with their own time horizons. A considerable part of this thesis consisted of finding the appropriate data, linking indices and extending time series; for a full specification of the data and complimentary data used, see appendix A2. Table 1 presents summary statistics.

Table 1. Descriptive statistics for the time horizon of the analysis. Real values expressed in logartihms.

Variable	Time period	Obs	Mean	Std. Dev.	Min	Max
$\boldsymbol{HPI^{Sthlm}}$	1900-2020	121	0.52	0.41	-0.11	1.65
$\boldsymbol{HPI^{Gbg}}$	1900-2020	121	0.44	0.42	-0.31	1.64
$\boldsymbol{Y}$	1900-2020	121	11.10	1.13	9.31	12.86
$\boldsymbol{D^{TOT}}$	1900-2020	121	-0.25	0.27	-0.76	0.32
$\boldsymbol{D^{M}}$	1900-2020	121	-1.94	1.08	-4.01	-0.21
$\boldsymbol{R}$	1900-2020	121	5.44	2.44	0.25	12.22
$\boldsymbol{CCI}$	1910-2020	111	0.04	0.18	-.41	0.44
$\boldsymbol{DEM}$	1900-2020	121	37423	35465	3053	163005

The table reports the logarithm of real house price indices for Stockholm $\boldsymbol{HPI^{Sthlm}}$ or Gothenburg $\boldsymbol{HPI^{Gbg}}$, the logarithm of real household income measured as real GDP $\boldsymbol{Y}$, the logarithm of real debt $\boldsymbol{D_t^{Type}}$ in the form of real total outstanding private credit stock to GDP $\boldsymbol{D^{TOT}}$ or the real total mortgage debt stock to GDP $\boldsymbol{D^{M}}$, the real reference rate ***R,*** the logarithm of the real construction cost index ***CCI*** and total immigration ***DEM*** to Sweden.

The data over the prices of houses (*permanenta småhus)* in Stockholm $\boldsymbol{HPI^{Sthlm}}$ and Gothenburg $\boldsymbol{HPI^{Gbg}}$ builds on the indices created in Söderberg et al. (2014) and Bohlin (2014). The authors develop a nominal house price index for Stockholm and Gothenburg respectively using the average sales price ratios – *köpesskillingskoefficientmetoden* – running from 1875 to 1957. Söderberg et al. (2014) gather a sample of 13 812 prices of sold residential properties and Bohlin (2014) amasses a sample of 6 883 sales transactions for the entire sample period. The authors link their own calculated indices from 1875 together with the ones from SCB to create indices spanning from 1875 to 2012. The index of Söderberg et al. (2014) is subsequently enhanced in Edvinsson et al. (2020). The authors first construct an index between 1818 and 1875 for the city of Stockholm, link it to the index of Söderberg, et al. (2014) and extend the end-period from 2012 until 2018. However, the extension from 1818 to 1875 is omitted due to difficulties finding time series for other relevant variables during this period. The index of Edvinsson et al. (2020) is used to fill in the period between 2012 to 2018. I use the house price index of SCB to extend the indices up until 2020. The index of Söderberg et al. (2014) covers the inner city of Stockholm from 1875 to 1957, the city of Stockholm between 1957 to 1969, the urban area of Stockholm county between 1969 to 1970 and the entirety of Stockholm county from 1970 onwards. The index of Bohlin (2014) covers transactions from Gothenburg city between 1875 to 1957, and from 1957 onwards Gothenburg and Bohus county. Data for Gothenburg from 2012 is only available over the greater Västra Götaland region. Thus, the index of Bohlin (2014) features Gothenburg and Bohus county up until 2012, which I extend to cover the wider Västra Götaland region from 2012.

The aggregate income variable $\boldsymbol{Y}$ is modelled as total GDP and comes from Edvinsson (2013a, 2013b & 2014). Data runs from 1875 to 2014 and is complimented by data from SCB. GDP is frequently used in the literature as a proxy for household income and while it doesn’t replace the accuracy of using household disposable income, it is available for the entire sample period.

Data over private credit $\boldsymbol{D_t}$ comes from Ahnland (2015) and runs from 1900 to 2012. I use complimentary data from SCB to fill in the period between 2012 to 2020. Private credit is usually modelled with the help of credit stock variables, such as aggregate bank lending, loan-to-GDP ratios or loan-to-income ratios (see for instance Hofmann, 2003; Oikarinen, 2009; Brissimis & Vlassopoulos, 2009). Ahnland (2015) collects the total outstanding debt stock of the private sector, therein bank credit, mortgage credit and ‘other credit’ in the form of consumption loans primarily. A decision had to be made whether to use real total debt $\boldsymbol{D^{TOT}}$ or real mortgage debt $\boldsymbol{D^{M}}$. While the use of the latter should be indicative of the borrowing behavior of households specifically in the pursuit of purchasing housing, housing mortgage has historically constituted a minor share of total private credit in Sweden (Ahnland, 2015). Only after the 1960's has mortgage debt overtaken the position as the dominant form of private credit. By relying solely on mortgage debt acquired on secondary mortgage markets and financed through bonds, other forms of bank lending tied to house prices such as consumption loans will be omitted.[8] Utilizing the total outstanding private credit stock, which also includes mortgage debt, is seemingly more suited to capture the effect of household borrowing behavior, household debt and bank lending over the entire period analyzed. Real debt is divided with GDP to avoid issues with multicollinearity.

The interest rate variable $\boldsymbol{R}$ is the so-called discount rate and spans the period 1900 to 2003. The discount rate was the effective reference rate up until 2002 when it was replaced by the "reference rate" –the period from 2003 to 2020 is subsequently complemented with the reference rate. Both the discount- and reference rates have been used to set effective lending rates of financial institutions and are therefore better determinants of actual household borrowing than the policy rate. This does mean that effective monetary policy decisions are not fully captured. On the other hand, the reference rates follow the policy rate, as the former is set twice every year according to the latter, which implies that they at least in part should account for monetary policy decisions. The interest rate variable is made up of yearly averages.

The housing stock variable consists of the Construction Cost Index ***CCI*** and comes from SCB. The variable runs from 1910 to 2020. Supply side variables of housing are hard to come by and, as Oikarinen (2009) points out, changes in supply side policies and legislation makes it hard to econometrically account for the housing stock. Instead the housing stock is proxied on the costs associated with construction, such as equipment, salaries and cost for materials.

Data over total immigration ***DEM*** is taken from SCB and spans the period between 1900 to 2020. Besides ***DEM*** and $\boldsymbol{R}$, all other variables are deflated with the consumer price index of Edvinsson & Söderberg (2010) and expressed in natural logarithms. The interest rate is

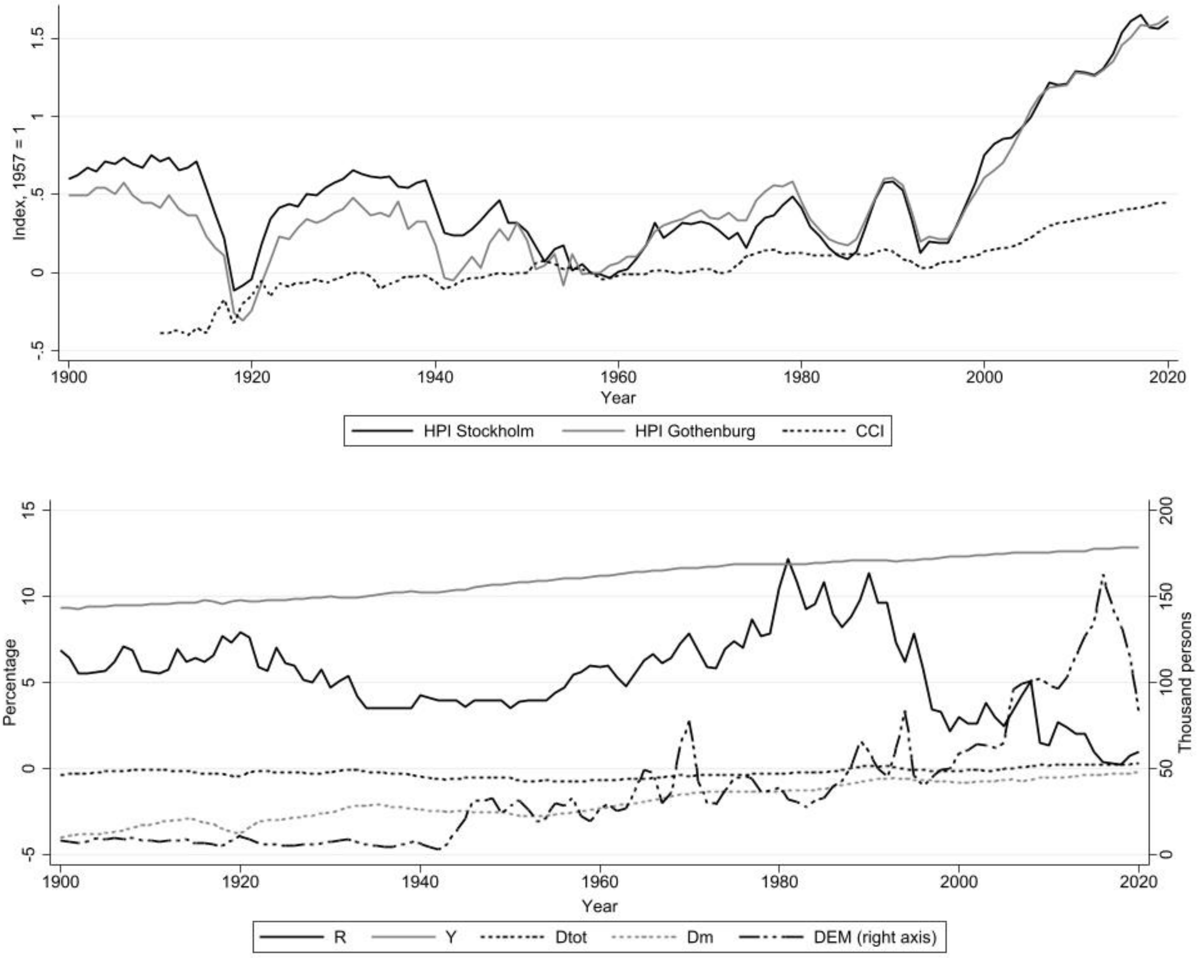
[8] Consumption loans are important to consider as they consist of transactions that are directly related to housing values, such as loans for home-renovations.

deflated in an ex post sense by annualized inflation rates according to $\boldsymbol{r_t} = \boldsymbol{i_t} - (\boldsymbol{p_t} - \boldsymbol{p_{t-1}})$.[9] All variables are presented figure 3.[10]

There are some possible caveats worth mentioning. The linking of time series and indices implies that there might be issues with data quality. While the complimentary sources of the SCB and the Riksbank have been chosen according to how well they fit the other time series they are linked to, the absence of smaller jumps cannot be completely guaranteed. The nature of the historical data also poses its challenges: it is hard to confirm validity of historical data sources and there is a risk of inaccuracy due to outdated methods of gathering and storing the data. The question of generalizability of the results is also worth mentioning. The underlying variables are for the entirety of Sweden whereas the house price indices are for Stockholm and Gothenburg. The dynamics of real house prices in Stockholm and Gothenburg might react differently to changes in the chosen variables as opposed to how real house prices for the entirety of Sweden might react. However, the inclusion of the two largest cities should be indicative of the development of real house prices as a whole and they do encompass a considerable amount of the overall population in the country between 1910 to 2020.

[9] This is done in place of subtracting the nominal interest rate with the change of inflation as the 20th century has seen heavy inflationary fluctuations which would give rise to huge swings in the real interest rate.
[10] The CPI of Edvinsson & Söderberg (2010) runs until 2014 and is subsequently complimented with the CPI of SCB.

*Figure 3. Real values of variables in natural logarithms**, 1900-2020.*



*The three month treasury bill rate and total immigration is not expressed in natural logarithms.
Source: Söderberg et al. (2014), Bohlin (2014), Edvinsson et al. (2020), Edvinsson (2013a, 2013b & 2014), Ahnland (2015), Sveriges Riksbank & SCB.

6. Method

6.1. Model specification

The literature heavily employs the error-correction framework to analyze the dynamics of house prices and its long-run cointegration equation with the chosen variables. Cointegration implies that there exists at least one linear combination of $\boldsymbol{n}$ non-stationary variables that is stationary. This mean that both deterministic and stochastic trends in the underlying data can be used to explain the co-movement of variables over time. Originally put forth in Engle & Granger (1987), a vector of variables $\boldsymbol{X_t} = (\boldsymbol{x_{1t}} \quad \cdots \quad \boldsymbol{x_{Kt}})$' is cointegrated of order $\boldsymbol{d}$ if there exists at least one linear combination that, with the help of at least one cointegrating vector $\boldsymbol{\beta} = (\boldsymbol{\beta_1} \quad \ldots \quad \boldsymbol{\beta_K})$, is integrated by an order less than $\boldsymbol{d}$, say $\boldsymbol{d} - \boldsymbol{b}$. In the two-variable case, the Engel-Granger test is utilized to regress two non-stationary variables and then testing the error for stationarity. In a multivariate case, Johansen's approach (Johansen, 1995) considers the possibility of $\boldsymbol{r} = \boldsymbol{k} - \boldsymbol{1}$ linearly independent cointegrating relationships for cases with more than two variables.

The Johansen approach transforms the general VAR(p)-model into a cointegrating VAR(p)-model. The VAR(p) takes the form $\boldsymbol{y_t} = \mathbf{A_1}\boldsymbol{y_{t-1}} + \ldots + \mathbf{A}_{\boldsymbol{K}}\boldsymbol{y_{t-k}} + \boldsymbol{\varepsilon_t}$, with $\boldsymbol{y_t}$ being a vector of dependent variables and $\boldsymbol{A_K}$ a vector of constants. If the variables are I(d), then there possibly exists a linear combination such that $\boldsymbol{y_t} \sim \boldsymbol{CI}(\boldsymbol{d} - \boldsymbol{b})$, which in turn makes the variables in the underlying system cointegrated. This can be formulated as a vector error correction model (VECM) by subtracting $\boldsymbol{y_{t-1}}$ from both sides and tested by analyzing the rank of the matrix $\mathbf{\Pi}$ carrying the potential cointegrating coefficients $\boldsymbol{\beta_k}$. Rewriting and accounting for the expected trend in the underlying model, we ultimately get

$$\Delta \boldsymbol{y_t} = \mathbf{\Gamma_1} \Delta \boldsymbol{y_{t-1}} + \ldots + \mathbf{\Gamma}_{\boldsymbol{k-1}} \Delta \boldsymbol{y_{t-k+1}} + \mathbf{\Pi} \boldsymbol{y_{t-1}} + \Upsilon \boldsymbol{\tau} + \boldsymbol{\mu} + \boldsymbol{\varepsilon_t} \qquad (5)$$

with $\mathbf{\Pi} = -(\boldsymbol{I_N} - \boldsymbol{A_1} - \ldots - \boldsymbol{A_K})$ and $\boldsymbol{\Gamma_i} = -(\boldsymbol{A_{i+1}} + \ldots + \boldsymbol{A_k})$ for $\boldsymbol{i} = \mathbf{1}, \ldots, \boldsymbol{k} - \mathbf{1}$. $\boldsymbol{y_t}$ is a **Kx1** vector of endogenous variables, $\boldsymbol{\mu}$ is a **Kx1** vector of constants**,** Υ is a **Kx1** vector of trend coefficients for the trend component $\boldsymbol{\tau}$ and $\boldsymbol{\varepsilon_t}$ is an $\boldsymbol{iid}(\mathbf{0}, \boldsymbol{I_2})$, **Kx1** vector of white noise error terms. The rank of the **KxK** matrix $\mathbf{\Pi}$ captures the number of long-run coefficients $\boldsymbol{\beta}$ and $\mathbf{\Gamma}_{\boldsymbol{t}}$ is a **KxK** matrix containing the speed of adjustment coefficients $\boldsymbol{\alpha}$ and the other short-run parameters.[11]

[11] Informally known as the "short run" coefficients, the loading parameters exhibit the variable's adjustment towards long run equilibrium, ultimately achieving the result in (7).

The interpretation of the results not necessarily intuitive. The speed of adjustment coefficient tells us the duration for a given variable to correct for past deviations from equilibrium due to changes in the other underlying variables in the system. As $\boldsymbol{\alpha}$ is given in percentages, for a given value of $\boldsymbol{\alpha}$, the variable will correct by $\boldsymbol{\alpha} \times \mathbf{100}$ percent towards equilibrium over the given data frequency − in our case annually. The short-run parameters of the other underlying variables on variable $\boldsymbol{x}$, when statistically significant, can be used to infer causality. That is to say, if short-run changes in $\boldsymbol{y}$ are statistically significant on the short-run dynamics of $\boldsymbol{x}$, then $\boldsymbol{y}$ 'causes' changes in $\boldsymbol{x}$. Granger-causality testing through the Wald test is also a viable option to infer causality between the variables. The long-run $\boldsymbol{\beta}$ coefficients represent the long-run cointegrating equation towards which the $\boldsymbol{\alpha}$ coefficients are expected to converge over time. When analyzing the long-run relationship, we normalize a variable to equal one and analyze how a percentage change in other underlying variables affect changes in the normalized variable.

Based on the theoretical model discussed in chapter 4, the data in chapter 5 and the methodological framework above, our estimated long-run equation, consisting of our vector of variables and the expected cointegrating vector $\boldsymbol{\beta}$, takes the form:

$$\boldsymbol{HPI_t^i + \beta_1 Y_t + \beta_2 D_t^{TOT} + \beta_3 R_t + \beta_4 CCI_t + \beta_5 DEM_t + \varepsilon_t = 0} \qquad (6)$$

which can be rewritten as

$$\boldsymbol{HPI_t^i = -\beta_1 Y_t - \beta_2 D_t^{TOT} + \beta_3 R_t + \beta_4 CCI_t - \beta_5 DEM_t + \varepsilon_t} \qquad (7)$$

$\boldsymbol{HPI_t^i}$ is the real house price index for Stockholm (expressed as $\boldsymbol{HPI_t^{Sthlm}}$) or Gothenburg (expressed as $\boldsymbol{HPI_t^{Gbg}}$), $\boldsymbol{Y_t}$ is real aggregate income, $\boldsymbol{D_t^{TOT}}$ is the total outstanding real private debt stock divided by GDP, $\boldsymbol{R_t}$ is the real interest rate, $\boldsymbol{CCI_t}$ is the real construction cost index and $\boldsymbol{DEM_t}$ is demographics expressed as total immigration to Sweden. As is prevalent, $\boldsymbol{\beta_1}$, $\boldsymbol{\beta_2}$ and $\boldsymbol{\beta_5}$ are expected to be negative as their respective variables are hypothesized to positively affect house prices. By similar logic, $\boldsymbol{\beta_3}$ and $\boldsymbol{\beta_4}$ are expected to be positive as their variables are expected to negatively affect house prices.

6.2. Hypotheses

Three main hypotheses are formed around the relationship of real house prices and the theoretically motivated, underlying variables. Taken as a given and therefore not subject to hypothesis testing is the existence of at least one cointegrated equation between the chosen variables.

H1. The long-run relationship is stable and the underlying variables carry signs according to theory as laid out in chapter 4. This means that increases in real income, real debt and immigration lead to rising house prices, and increases in the real interest rate and real construction costs lead to falling house prices.

Table 2. Hypothesized effect of underlying variables on house prices in the long-run.[12]

	Y_t	D_t	R_t	CCI_t	DEM_t
HPI_t^i	+	+	-	-	+

H2. The speed of adjustment towards long-run equilibrium is statistically significant for every underlying variable. House prices adjust slower than similar findings for house prices in the literature for other industrialized countries. As the Swedish housing market throughout the entire sample period has been subject to extensive market regulation, such as rent regulation, the building- and planning monopoly and financial market deregulation, house prices should showcase a considerable degree of rigidity. Other variables in the system should therefore be responsible for more of the error-correction towards the long-run relationship. Implicitly, housing is assumed to be more prone regulation than the underlying variables, such as access to credit.

H3. The short-term relationship between the underlying variables has changed markedly around the mid-1980's and early 1990's. Specifically, a mutually reinforcing relationship has emerged between real house prices and real credit, in part due to the financial market deregulation and tax reform. This finds support in the literature (see for instance Fitzpatrick & McQuinn, 2004; Oikarinen, 2009). As this period marks a loosening of credit constraints of households and better access to credit, the role of debt on house prices should intensify. The opportunity to extract equity from housing to finance other forms of consumption should intensify real house prices to both real income and real debt. The interest rate should closely follow that of real debt and is therefore expected to be ambiguous. Construction costs affect the number of available housing units and carries an effect on economic growth. The rate of construction has also increased greatly since the 1980's, and is therefore expected to have

[12] We remember that the signs as given in the result in chapter 7 for the long-run equation will be flipped, as the variables in (6) will be moved to the other side as in (7).

intensified. The steady increase in immigration between 1940 to 2015 should imply a reinforced relationship with regards to every underlying variable in the system.

7. Results

For any VECM specification to work, the underlying variables potentially sharing at least one cointegration relationship must be unit-root non-stationary. To test this, Augmented Dickey-Fuller (ADF) and the Phillips-Perron tests are conducted and found in appendix A2. The tests are performed with a constant and trend, and a linear time trend, respectively. All variables are non-stationary according to both tests. Taking first differences indeed confirm all variable to be I(1); however ***DEM*** is extremely close to being I(0).[13] Further DF-GLS tests confirm ***DEM*** to be I(1) at the 5 percent level. Because of this ***DEM*** enters the model as exogenous. To account for potential structural breaks, three dummies are created and treated as exogenous. Both world wars saw sharp downturns in economic growth and subsequently in house prices, even as Sweden did not participate in the theatre of war. Furthermore, the financial market liberalization and the "Tax Reform of the Century" during the latter 1980's and early 1990's potentially present a structural break.[14] Further dummy variables to control for other possible structural breaks were considered but ultimately dropped. As the included variables control for housing demand, housing supply, mobility on the housing market, monetary policy and household's preference to risk and borrowing, major institutional change are presumed to be captured by the included variables.

The estimates of optimal lag length are reported in appendix A3. Optimal lag-length is tested with four max-lags and the most parsimonious information criteria is chosen. According to the Schwartz-Baysian Information Criteria (SBIC), one lag is preferred. Underparameterization runs the risk of inducing finite sample bias and serially correlated errors while overparameterization imposes penalties in the form of loss of efficiency – but consistency remains (Gonzalo, 1992).[15] The annual frequency of the data is best suited for one or two lags and is expected to account for any serial correlation (Woolridge, 2013). Consequently, one lag is chosen for both Stockholm and Gothenburg. To test for the number of cointegrating relationships, Johansen's Trace test is used. The null of no cointegration is tested against the hypothesis that there is at most one linear combination that is stationary. If

[13] All variables are referred to by their letter-notation from table 1 henceforth.
[14] The dummies take the value 1 when the years of interest are in effect and 0 otherwise.
[15] In fact, maximum likelihood in the error-correction-framework still performs more efficiently with serially correlated errors than both single- and multiequation models such as OLS and GLS without serial correlation. See Gonzalo (1992) for more.

the null is rejected, the hypothesis of one linear stationary combination is tested against the hypothesis of at most two cointegrating relationships. And so on. This procedure is repeated until the null no longer can be rejected. All tests include a constant trend component. The Trace test showcase that there is no more than one cointegrating relationship between the chosen variables for both Stockholm and Gothenburg at the specified lag-lengths. The Johansen's Trace test results are presented in table 2.

The long-run $\boldsymbol{\beta}$ coefficients are reported in table 3. The data is normialized with regards to house prices, which equals one. Both models show the expected signs according to the previously formed hypotheses and all variables are statistically significant on the one percent level. As the included variables except for $\boldsymbol{R}$ are expressed in their natural logarithms, the interpetation of the coefficients is that of elasticities. The income elasticity of $\boldsymbol{HPI^{Gbg}}$ in is greater than $\boldsymbol{HPI^{Sthlm}}$ where a one percent increase in $\boldsymbol{Y}$ leads to a 0.24 and 0.39 percent increase in house prices in the respective city. The debt elasticity of $\boldsymbol{HPI^{i}}$ is 1.34 and 1.12 in Stockholm and Gothenburg respectively. This implies that changes in $\boldsymbol{HPI^{i}}$ are more sensitive to changes in $\boldsymbol{D^{TOT}}$ than $\boldsymbol{Y}$ – the literature tends to find the effects of $\boldsymbol{Y}$ to be greater than that of $\boldsymbol{D^{TOT}}$ (see for instance Holly & Jones, 1997; Hofmann, 2004; Oikarinen, 2009; Berki & Szendrei, 2017). As expected, $\boldsymbol{R}$ and $\boldsymbol{CCI}$ negatively affect $\boldsymbol{HPI^{i}}$. Decreases (increases) in the $\boldsymbol{R}$ induce households to borrow (save) and purchase ("sell") housing. $\boldsymbol{HPI^{Sthlm}}$ and $\boldsymbol{HPI^{Gbg}}$ changes opposingly by 17.34 and 16.92 percent respectively to a percentage change in the interest rate. Similarly, the construction cost elasticity of $\boldsymbol{HPI^{Sthlm}}$ and $\boldsymbol{HPI^{Gbg}}$ leads to a 1.73 and 1.77 change respectively – when supply increases it logically follows that demand decreases.

Table 3. Johansen's Trace test for cointegration with p=1 lags.

Cointegrating relationships	**r = 0**	**r ≤ 1**	**r ≤ 2**
1% Critical value	**76.07**	**54.46**	**35.65**
Stockholm	93.32	34.00*	12.31
Gothenburg	87.57	27.44*	13.72

All tests are performed with a constant trend specification. * Confirms the number of cointegrating relationships.

Table 4. Estimated long-run $\boldsymbol{\beta}$coefficients of house prices and underlying variables between 1910 to 2020.

	HPI^i	Y	D^{TOT}	R	CCI	Constant
Stockholm	1	-0.2395*** (0.0869)	-1.3427*** (0.1801)	0.1734*** (0.0178)	1.7329*** (0.4241)	0.9727
Gothenburg	1	-0.3920*** (0.0909)	-1.1188*** (0.1885)	0.1692*** (0.0186)	1.7723*** (0.4438)	2.7952

*, **, *** indicate $p \leq 10\%$, $p \leq 5\%$ and $p \leq 1\%$ significance, respectively. Standard error in parenthesis.

The speed of adjustment coefficients $\boldsymbol{\alpha}$, model fit and specification tests are presented in table 5. The real house prices of both cities and their respective cointegrated equations are plotted in figure 4. The nature of the VECM implies that the error-correction coefficients in their first-difference representation of any lag-length of p-lags becomes $\boldsymbol{p-1}$. As the chosen lag-length is one, $\boldsymbol{p-1 = 1-1 = 0}$. Thus, the system features no lags to explain short-run causality between the variables. The adjustment coefficients are all statistically significant which implies that the overall specification is sound. $\boldsymbol{HPI^{Sthlm}}$ and $\boldsymbol{HPI^{Gbg}}$ adjust 10.05 and 11.45 percent towards the long run equilibrium over a year respectively. It would take around 10 years for house prices to single-handedly correct for disequilibrium, which is inherently more sluggish than similar findings in the literature.[16] However, $\boldsymbol{\Delta HPI^i}$ still showcases a greater degree of error-correction than every other variable except $\boldsymbol{\Delta R}$. $\boldsymbol{\Delta Y}$, while statistically significant, shows the incorrect sign and could as thus be treated as weakly exogenous. However, due to the lag length, treating $\boldsymbol{\Delta Y}$ as weakly exogenous is all but impossible. For now, we let the oddity of the sign of $\boldsymbol{\Delta Y}$ be. $\boldsymbol{\Delta D^{TOT}}$carries the correct sign and is of a similar sluggish nature as house prices, correcting by 5.87 and 4.82 percent annually towards equilibrium. This implies that when other variables overshoot the long-run equilibrium, $\boldsymbol{\Delta D^{TOT}}$ adjust up towards the long-run equation. $\boldsymbol{\Delta R}$ exhibits a large adjustment coefficient, correcting by 92.52 and 90.58 percent towards equilibrium per year. $\boldsymbol{\Delta CCI}$ corrects very similarly in Stockholm and Gothenburg, by 4.39 and 4.36 percent respectively – the lowest correction speed of all included variables. This is sensible, as construction is a timely process and could be considered more rigid than adjustments in the other parameters.

The overall model fit seems to withstand the standard battery of diagnostics tests. The error-terms are serially uncorrelated and stationary. The Jarque-Berra test for normality of

[16] Kishor & Marfatia (2017) find that it on average takes between 3 to 4 years for house prices to adjust. Similar findings are reported in Egert & Mihaljek (2007) and Holly & Jones (1997).

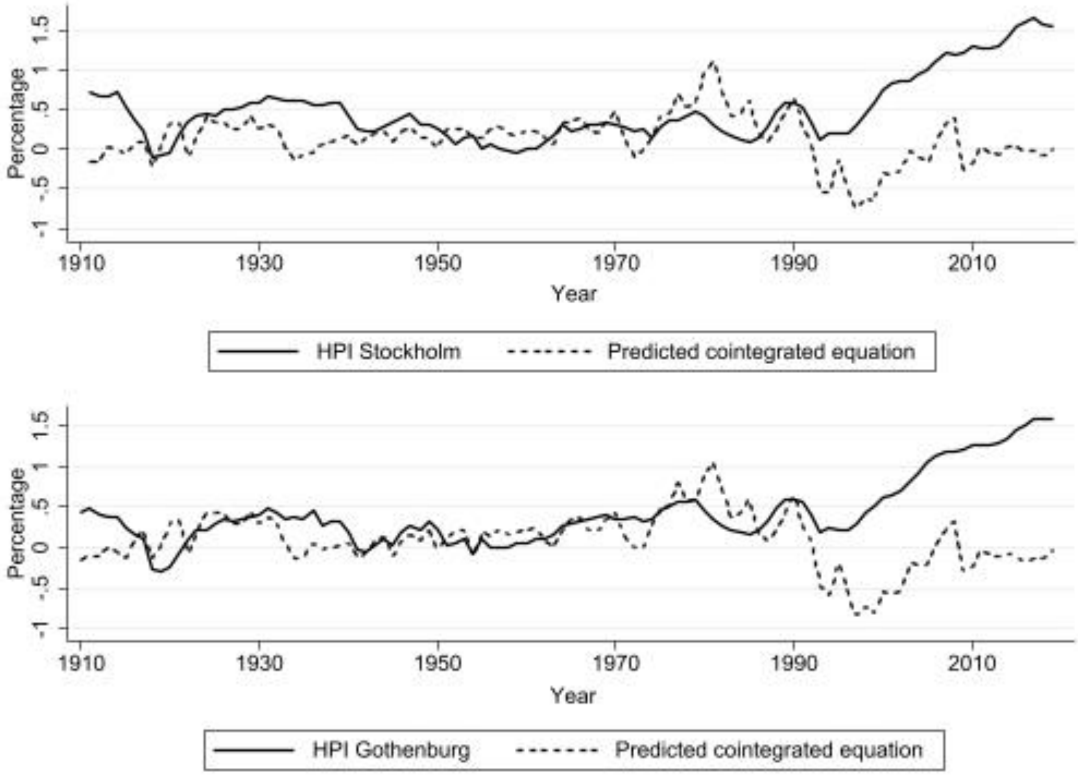
errors inspects the existence of an asymptotic χ^2-distribution but showcases the existence of non-normal error terms. As we assume $\boldsymbol{\varepsilon_t} \sim \boldsymbol{iid}(\mathbf{0}, \boldsymbol{I_2})$, and where $\boldsymbol{E}(\boldsymbol{\varepsilon_t}) = \mathbf{0}$ and $\boldsymbol{Var}(\boldsymbol{\varepsilon_t}) = \boldsymbol{I_2}$ seems to hold by visual inspection of the errors in appendix A5, the parameter estimates are still consistent at the loss of efficiency in the case of non-normality. In other words, the values are true but there exists some specification providing more efficiency. One way to get around this would be to construct further dummies and control for institutional change or other possible structural breaks. Ultimately, the independency and identical distribution of the error terms allows for efficient estimates and does allow for inference.

Table 5. The estimated adjustment coefficients $\boldsymbol{\alpha}$ of house prices and underlying variables between 1910 to 2020.

	α^{Sthlm}	α^{Gbg}
ΔHPI^i	-0.1005*** (0.0313)	-0.1145*** (0.0304)
ΔY	-0.0708*** (0.0132)	-0.0721*** (0.0122)
ΔD^{TOT}	0.0587*** (0.0200)	0.0482*** (0.0191)
ΔR	-0.9252*** (0.3521)	-0.9058*** (0.3328)
ΔCCI	-0.0439*** (0.0139)	-0.0436*** (0.0131)
	Stockholm	**Gothenburg**
Log likelyhood	640.83	632.14
AIC	-11.03	-10.88
HQIC	-10.69	-10.54
SBIC	-10.20	-10.04
χ^2	39.35	36.96
JB test	0.00	0.00
Skewness	0.00	0.00
Kurtosis	0.00	0.00
Stability	Yes	Yes
Stationarity CE	-3.533***	-3.230**
Stationarity $\boldsymbol{\varepsilon_t}$	-7.382***	-8.868***
LM test P = 1	0.8956	0.6812
LM test P = 2	0.5714	0.3327
LM test. P = 3	0.9238	0.5897
LM test. P = 4	0.2044	0.2866

χ^2 are given for ΔHPI^i. The JB test is the Jarque-Berra goodness-of-fit-test. The LM test is the Lagrange-Multiplier test for serial correlation in the residuals. The JB test is the Jarque-Berra goodness-of-fit-test. Stability implies that all eigenvalues are within the unit circle. Stationarity of the cointegration equation (CE) and the residual of the error-correction model ε_t are the ADF-test statistics with a no trend-specification. *, **, *** indicate $p \leq 10\%$, $p \leq 5\%$ and $p \leq 1\%$ significance, respectively. Standard error in parenthesis.

Figure 4. The actual real house prices of Stockholm and Gothenburg, and their estimated cointegrated equations, 1911 to 2020.



The long-run relation seems sensible and for much of the 20th century real house prices in both cities do not seriously diverge from the estimated cointegrated equation. As is apparent in figure 4, the beginning of the 1990's marks a structural break and there is reason to believe that some fundamental change in the underlying short-term relationship took place. Although partially controlled for by the usage of dummies, this break could in part explain the non-normality of the error terms. However, the current model specification omits the short-run coefficients that contain information on the chain of causality. Instead the model is refitted around two sub-samples between 1910 to 1979 and 1980 to 2020, and assessed with the Wald test.[17] The 1980's and 1990's implied major structural reform through the liberalization of financial markets and the "Tax Reform of the Century". The subsequent decrease in mortgage transaction costs by the establishing of secondary mortgage markets lead to increased household solvency and equity extraction of housing (Gerardi et al., 2010). The tax reform introduced, among other things, property taxation and decreased income taxation. Overall, this period should indicate a loosening of credit constraints and increased income which

[17] On a more technical note, the lack of short-run dynamics due to the chosen lag-length makes it impossible to assess causal direction based on the short-run parameters.

should lead to a strengthening in Granger-causality running between ΔHPI^i, ΔY and ΔD^{TOT}. While increased equity extraction of housing should imply a strengthening of ΔHPI^i to both ΔY and ΔD^{TOT}, the property tax could partially offset this effect. While ΔR partially dictates the magnitude of ΔD^{TOT}, financial market liberalization could manifest itself in real debt directly as opposed to the actual interest rate environment. Therefore, the causal effect on and of ΔR is expected to be ambiguous. The effect of ΔCCI is expected to have intensified, specifically to ΔHPI^i and ΔD^{TOT}**,** as construction costs in Sweden since the 1980's has risen by historical proportions until the present day.

A recursive ordering along the lines of Hofmann (2004) and Oikarinen (2009) is employed with ΔY , ΔHPI^i, ΔD^{TOT}, ΔR and ΔCCI entering the VECM as endogenous variables in that order. ΔDEM enters as exogenous. The period from 1910 to 1979 encompasses 69 observations and the period from 1980 to 2020 consists of 40 observations. ΔY is assumed to be sticky and is contemporaneously unaffected by changes in other variables. ΔHPI^i is assumed to be rigid but able to affect ΔD^{TOT} and the ΔR, whereas changes in ΔHPI^i are not allowed to affect ΔY. ΔD^{TOT} does not drive the latter two and only affect ΔR.[18] As is usual in the literature, ΔR carries a delayed real effect on the macroeconomy and is accordingly ordered after ΔY , ΔHPI^i and ΔD^{TOT}. ΔCCI is assumed to be a drawn-out process and therefore comes last in the ordering. ***DEM,*** while assumed to be important for the system after the 1940's, is allowed to only affect the underlying system exogenously.

The SBIC recommends one lag for each model, whereas other IC gives between three and four for each model. The models are fitted with two lags which, after first-differencing in the error-correction model, yields one lag and thus enabling short-term dynamics.[19] The choice of two lags saves up valuable degrees of freedom while still allowing analyzing causality in the short-run dynamics through the Wald test. Johansen's Trace test showcases one cointegrated relationship for each model. The Wald test results are presented in table 5 and model specification criteria in appendix A4.

The third hypothesis **H3,** that the short-run dynamics have changed markedly following the mid-1980's and early 1990's, finds strong support. ΔHPI^i is not Granger-caused by any of other underlying variables in the system in the first sub-sample whereas in the second sub-

---

[18] It is assumed that the amount of debt needed to purchase a house depends on the price of the house and how great one's income is. In essence, both the price and income is already set before securing a loan.
[19] Some models were recommended either one or three lags. However, to save degrees of freedom while still allowing for short-run dynamics, two lags were chosen.

Table 6. Wald test results of Granger-causality.

Stockholm		ΔY	ΔHPI^i	ΔD^{TOT}	ΔR	ΔCCI	Equation
1910-1979	ΔY	0.43	0.30	0.47	0.64	0.10	0.40
	ΔHPI^i	**0.01***	0.48	**0.08***	0.78	0.37	0.29
	ΔD^{TOT}	**0.01***	0.54	**0.01***	0.74	0.34	0.60
	ΔR	0.13	0.56	**0.06***	0.33	**0.00***	**0.00***
	ΔCCI	**0.00***	0.18	0.78	0.59	**0.00***	.
1980-2020	ΔY	0.13	**0.01***	**0.01***	**0.00**	0.50	**0.00***
	ΔHPI^i	**0.01***	**0.00***	0.11	**0.00**	0.68	**0.00***
	ΔD^{TOT}	0.29	**0.01***	0.11	**0.06**	0.27	0.17
	ΔR	0.10	0.61	0.57	0.77	0.81	0.81
	ΔCCI	0.12	**0.02***	**0.02***	**0.01**	**0.01***	.

* indicates significance on any conventional level; P-values are given.

Gothenburg		ΔY	ΔHPI^i	ΔD^{TOT}	ΔR	ΔCCI	Equation
1910-1979	ΔY	0.88	0.81	0.99	0.39	0.15	0.55
	ΔHPI^i	**0.00***	**0.02***	**0.02***	0.38	0.54	**0.05***
	ΔD^{TOT}	**0.01***	0.99	**0.01***	0.53	0.39	0.58
	ΔR	0.16	0.81	**0.06***	0.20	**0.01***	**0.01***
	ΔCCI	**0.00***	0.10	0.71	0.73	**0.00***	.
1980-2020	ΔY	0.18	**0.00***	**0.01***	**0.00**	0.47	**0.00***
	ΔHPI^i	**0.00***	**0.00***	**0.02***	**0.00**	0.24	**0.00***
	ΔD^{TOT}	0.43	**0.01***	0.17	0.11	0.41	0.26
	ΔR	**0.06***	0.43	0.45	0.98	0.90	0.90
	ΔCCI	0.15	**0.01***	**0.01***	**0.01**	**0.01***	.

* indicates significance on any conventional level; P-values are given.

sample $\Delta Y, \Delta D^{TOT}$ and ΔCCI all Granger-cause ΔHPI^{i}. By comparison, ΔHPI^{i} Granger-caused ΔY and ΔD^{TOT} in the first sub-sample while Granger-causing almost all other variables except for ΔCCI in the second sub-sample. ΔD^{TOT} was caused by ΔHPI^{i} and ΔR in the first sub-sample, but subsequently causes both variables after the 1980's. Among other things, this suggests that a mutually reinforcing relationship between credit- and house price cycles has emerged in Gothenburg. In the case of Stockholm, house price cycles caused credit cycles prior to the 1980's, which has since changed causal direction. Interestingly, ΔR has at least in part has started to capitalize more on ΔHPI^{Sthlm} in the second sub-sample. The role of ΔY on the entire underlying system has become more important, going from not inferring causality to any variable in the system to causing all but ΔCCI. ΔD^{TOT} caused ΔY in the first sub-sample but causality has changed direction after the 1980's. Taken together, the result indicates increased interchangeability between real income, real debt and real house prices.

Causality running from ΔR to the underlying variables has completely flipped in the second sub-sample, where ΔR instead is caused by $\Delta Y, \Delta HPI^{i}$ and ΔCCI . ΔD^{TOT} is also a causing ΔR in Stockholm. Granger-causality from ΔR to ΔD^{TOT} ceased to exist in the second sub-sample. Household borrowing was manifested in both ΔR and ΔD^{TOT} between 1910 to 1980, but seems to fully capitalize through ΔD^{TOT} following the 1980's. This result suggests that ΔR is set in a reactive manner and according to the interplay between ΔD^{TOT}, $\Delta Y, \Delta HPI^{i}$ and ΔCCI, which themselves have become more interlinked, to influence the borrowing behavior of households.

Outside of ΔY, ΔCCI is the only variable to Granger-cause every other variable in the underlying system in both cities in the second sub-sample. No variable except ΔCCI itself causes ΔCCI after the 1980's, indicating that the supply-side is of vital importance when assessing the dynamics of house prices.

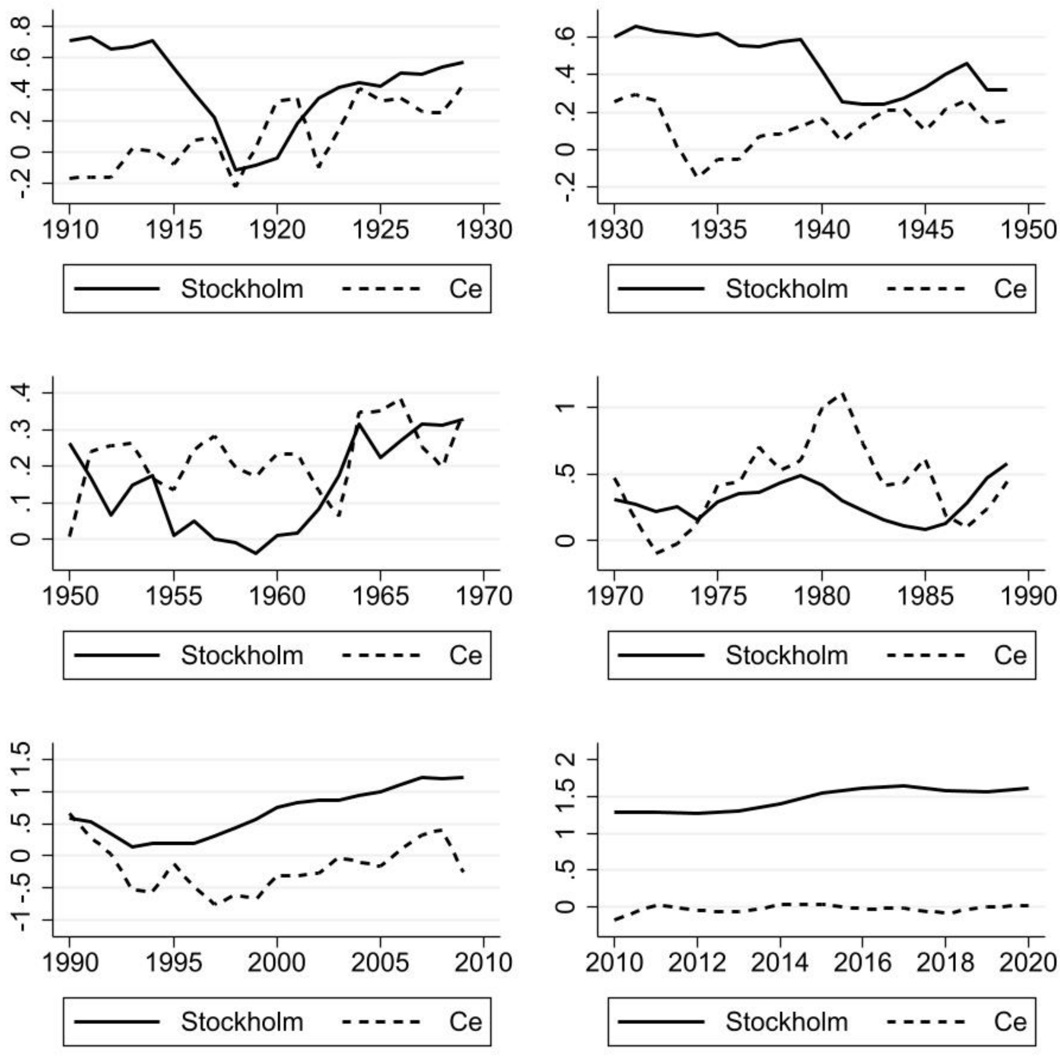
The recursive ordering shows a strengthening from ΔY and ΔHPI^{i} to the other variables in the equation, but shows a diminishing causal link running from ΔD^{TOT} to ΔR and ΔCCI. The role of ΔR on ΔCCI is non-existent.

8. Analysis

There is one cointegrated relationship between the chosen variables and the signs of the variables in the long-run relationship work according to **H1**, with the exception of immigration which, due to methodological reasons, entered the system as exogenous**.** The process is stable and stationary. The long-run relationship show that the debt- vis-à-vis income elasticity of housing is greater, implying that house prices react more strongly to changes in real debt than they do to real income. Changes in other variables are also comprehensive on changes in house prices. Taken together, **H1** is to be viewed as true. The sluggish adjustment towards long-run equilibrium implies that real house prices in both cities is more rigid than findings for other cities in the literature – possibly the result of extensive regulation throughout the majority of the 20^{th} century. This would imply **H2** to be true. Yet, house prices still error-correct more than the majority of the other variables in the system which implies greater rigidity in the underlying variables under the given model specification. As a result, **H2** is to be viewed as partly true. The period after 1980 marks a shift in the short-run dynamics from the period between 1910 and 1980. Specifically, from 1911 to 1979, a causal relationship from house prices to real income and real debt was prevalent whereas the relationship since has become mutually reinforcing in Gothenburg but only running from real debt to real house prices in Stockholm. Therefore, **H3** is to be viewed as partly true. The entire sample period is divided up into six 20-year-segments in figure 5 and 6 for Stockholm and Gothenburg respectively.

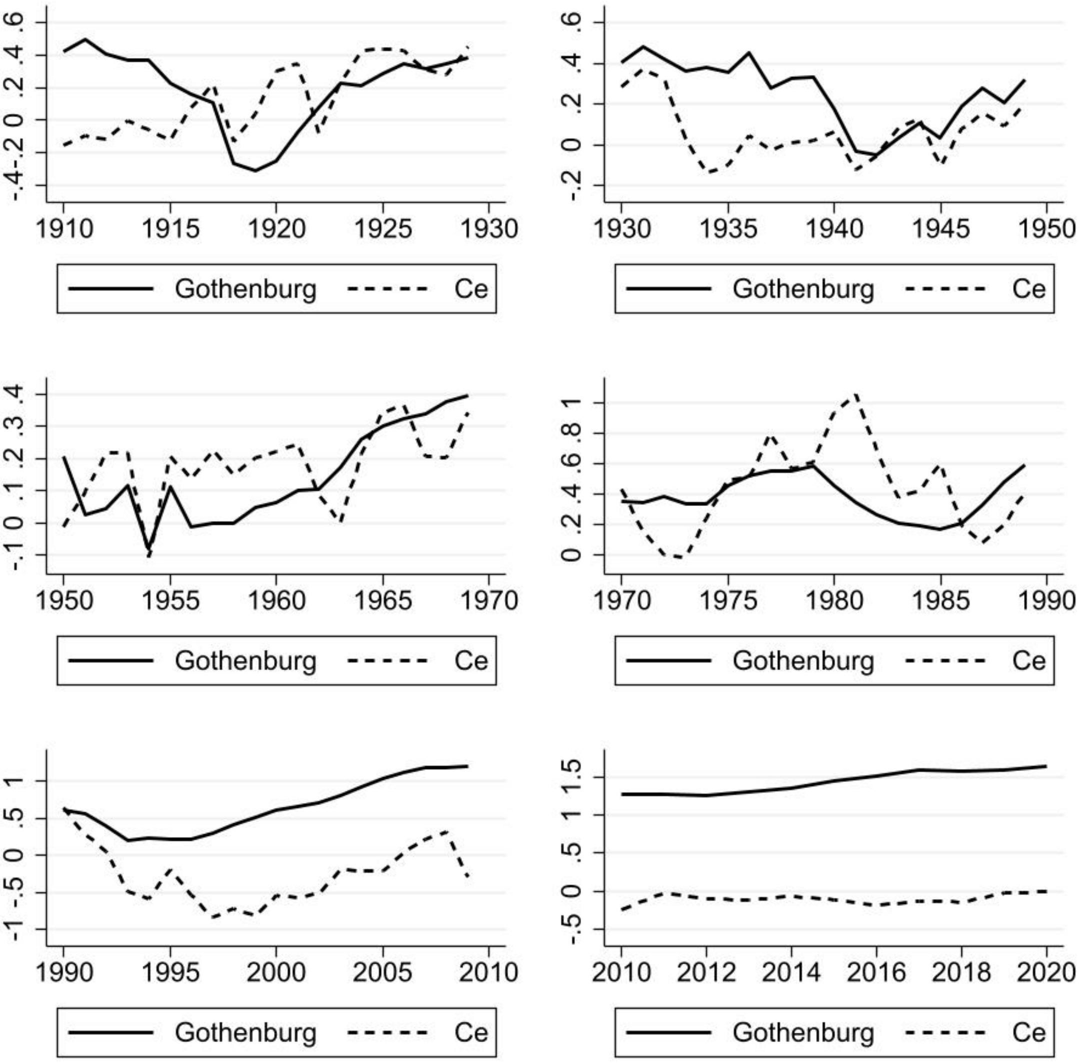
The financial crisis of 1907 and subsequently the period leading up to 1915 suggests an overvaluation of real house prices compared to the cointegrated equation. The fall in construction due to serial striking and lockouts following the financial crisis in 1907 seemingly created a fall in supply (and most likely income), leading to upwards pressure on house prices. The steep economic decline in 1914 with stagnating construction clearly put a downwards trend on house prices and convergence towards the cointegrated equation. Between 1916 and 1917, imports were falling due to the ongoing war and a food crisis broke out as a result of bad harvests in Northern Europe (Edvinsson & Hegelund, 2016). The war also contributed to price increases in building materials and rising interest rates. This evidently contributed to the fall in house prices towards the underlying fundamentals. The end of the war and the first iteration of rent control made house prices overvalued in Stockholm and undervalued in Gothenburg – possibly due to differences in growth of the cities. Indeed, the inter-war period saw positive net-migration (or negative net-immigration) and increased construction in Gothenburg (Bohlin, 2014), both variables which were hypothesized (and subsequently shown) to negatively affect house prices. The deflation crisis first half of the 1920's saw rising house prices in Stockholm, while house prices in Gothenburg remained undervalued.

Figure 5. Real house prices (Stockholm) and the long-run cointegrated equation (Ce) divided into periods, 1910 to 2020.



Notable for the period between 1930 to 1940 is the clear overvaluation of house prices in both cities. The Great Depression led to a decline in GDP by 10 percent in 1931 and another 8 percent in 1932 (Edvinsson & Hegelund, 2016). This was however not reflected in actual house prices. Convergence was achieved shortly after the outbreak of the second world war, which also saw the introduction of supply-side regulation of financial markets and further rent regulation. The results would indicate that throughout the 1940's, these reforms prohibited house prices from noticeably diverging from the cointegrated equation. The evidence of large debt elasticity of housing implies that decreased credit accessibility due to financial market regulation should decrease volatility of house prices – which is evident during this period.

Figure 5. Real house prices (Gothenburg) and the long-run cointegrated equation (Ce) divided into periods, 1910 to 2020.



In line with the “Planning and Building law” in 1947 a shift from over- to undervaluation of house prices in both cities seem to have commenced. Privately-owned land become more inaccessible and future capital gains on property decreased. This also coincided with the regulation on the lending decisions and lending rates of commercial banks in 1951. Between 1950 to 1960, the population growth in both cities also halted (Waldenström, 2014; Edvinsson, et al. 2020). This period marks a fall in demand for land and housing, resulting in suppressed house prices not reflected in the underlying fundamentals. Between 1955 and 1965 house prices started converging towards the cointegrated equation. The "Million Programme" in 1965 with its emphasis on centrally planned construction saw a large increase in output and halted the upwards-sloping trend in house prices – specifically noticeable in Stockholm between 1963 to 1965. The cointegrated equation would instead suggest a continued rise in house prices. The oil crises of the 1970's implied expansive fiscal policy in an attempt to stave off inflationary pressure, which ultimately led to rising unemployment. Economic growth and real income decreased. This was not reflected in actual house prices. As a result, from 1970 to 1975, the cointegrated equation suggests that housing was overvalued in both cities.

From 1975 to around 1979, real house prices closely follow the cointegrated equation. The establishing of secondary mortgage markets and easier credit access through the removal of credit ceilings didn't come into effect before the latter part of the 1980's, which seems to be the driver in the rise of both actual house prices and the cointegrated equation. The reforms created inflationary pressure on house prices and up until 1990 – just before the crisis of 1990 to 1994 – the relationship co-moved. The crisis implied a large fall in the cointegrated equation and ensuing fluctuations, but only a small decrease in actual house prices. From around 1997, both actual house prices and the cointegrated equation started rising.

Between 1997 to 2020, the gap between actual house prices and the underlying macroeconomic fundamentals, while moving together, has continued to diverge, suggesting an ever-increasing overvaluation of house prices. In 2020, actual house prices were 2.5 times higher than what the fundamentals would indicate. Structural reform followed the financial crisis of 2008 and the subsequent European debt crisis of 2012 in an attempt to increase financial stability. Demand side regulation include a mortgage loan cap introduced in 2010 and amortization requirements introduced in stages in 2016 and 2018. Both reforms have increased the difficulties for less well-off individuals to purchase their homes and worsened their position *relative* to other groups (Eklund, 2016; Bäckman, 2019). These reforms have also done seemingly little in staving off inflationary pressure on house prices during the 2010's, as is evident by the continued convergence in actual house prices from the cointegrated equation above. On the supply side, construction – which has been proven to carry a statistically significant negative effect on house prices – continues to be low in part because of the municipal planning monopoly, which contributes to drawn-out approval processes of new housing (Lind, 2016).

It is worth noting that financial stability is not a policy goal of the Swedish Riksbank, which conducts monetary policy exclusively with their inflation target of two percent in mind. In other words, financial stability is of little concern to its monetary policy decisions. While the low interest rate environment and comprehensive quantitative easing has driven the Riksbank's decision making, upwards inflationary pressure seem to have manifested in house prices as opposed to the goods market as a result.

9. Concluding Remarks

The aim of this thesis has been to analyze the historical long- and short-run dynamics of house prices in the Swedish cities of Stockholm and Gothenburg with theoretically motivated, fundamental variables. These have consisted of real income, real debt and the real interest rate to model the macroeconomy, as well as the supply side through real construction costs and demographics in the form of total immigration. Three hypotheses were formed: **H1:** The long-run relationship is stable and the underlying variables carry signs according to theory. **H2:** The adjustment towards long-run equilibrium for house prices should be slower than other industrialized countries as found in the literature. **H3:** The short-term relationship between the underlying variables has changed around the mid-1980's and early 1990's, and a mutually reinforcing relationship have emerged between real house prices and real credit. The hypotheses are to be viewed as true, partly true and partly true, respectively.

A long-run, stable cointegrated relationship is found between the chosen variables. The underlying variables all explain fluctuations in house prices in the long-run on a one percent significance level. The debt elasticity of house prices is 1.34 and 1.12 and income elasticity of house prices is 0.24 and 0.39 in Stockholm and Gothenburg respectively. The effects of real income are lower than that of real debt, a relationship generally found to be reversed in the literature for other industrialized countries. Real house prices seem to be more sluggish when adjusting towards long-run equilibrium than real house prices in other cities, taking around 10 years to single-handedly adjust towards equilibrium. Greater rigidity in the underlying variables in the underlying model specification is found compared to rigidity in house prices. Evidence is found that the short-run dynamics of the cointegrated relationship changed after 1980, with the causality of real income and real debt onto house prices intensifying markedly. House price cycles drove credit cycles throughout the majority of the 20^{th} century, while the relationship has since the 1980's become mutually reinforcing in Gothenburg and exclusively running from real debt to real house prices in Stockholm. While house prices have fluctuated between under- and overvaluation compared to the long-run relationship, actual house prices were 2.5 times higher than what the fundamentals would indicate in 2020.

Further research into the dynamics of rent regulation would allow for analysis over multiple decades and allow for testing of both theory and empirics. The asset market approach stipulates that if the hypothetical rent cannot adjust to changes in user costs, all the adjustment towards equilibrium has to happen in prices. How does the sales price of rent regulated apartment buildings react to changes in user costs compared to marked priced housing as used in this thesis? Specific reforms such as the "Planning and Building law" of 1947 warrant more analysis as well, whereas more unconventional factors such as construction clearly is of great importance and should be further analyzed. The understanding of historical house price dynamics in other countries, similarly to what has been done in this thesis, continues to be an avenue of interest.

References

Ahamada, I. & Sanchez, J. 2013. "A Retrospective Analysis of the House Price Macro-Relationship in the United States". International Journal of Central Banking (2013), 03.

Ahnland, L. 2015. "Private debt in Sweden in 1900–2013 and the risk of financial crisis". Scandinavian Economic History Review, 63, 3: 302–323.

Agnello, L., Castro, V. & Sousa, R.M. 2019. "The Housing Cycle: What Role for Mortgage Market Development and Housing Finance?". Journal of Real Estate Finance & Economics, (2020), 61:607–670

Andersson, F. NG. 2020. "The Quest for Economic Stability: A Study on Swedish Stabilization Policies 1873–2019". Lund University School of Economics and Management Working Paper (2020), 16.

Andersson, R. & Söderberg, B. 2012. "Elimination of Rent Control in the Swedish Rental Housing Market: Why and How?" J. Hous. Res. 21, 159–181.

Berki, T. & Szendrei, T. 2017. "The cyclical position of housing prices – a VECM approach for Hungary". MNB Occasional Papers 126

Brissimis, S. N. & Vlassopoulos, T. 2009. "The interaction between mortgage financing and housing prices in Greece". Journal of Real Estate Economics 39, 146–164.

Broberg, O. 2014. "Globalisering, entreprenörskap och humankapital" in *Det svenska näringslivets historia 1864-2014* (eds. Mats Larsson). Centrum för Näringslivshistoria & Dialogos förlag.

Jan Bohlin. 2014. "A price index for residential property in Göteborg, 1875–2010", in *Historical Monetary and Financial Statistics for Sweden, Volume II: House Prices, Stock Returns, National Accounts, and the Riksbank Balance Sheet, 1620–2012.* (eds. Rodney Edvinsson, Tor Jacobson and Daniel Waldenström). Sveriges Riksbank and Ekerlids.

Calza, A., Monacelli, T. & Stracca, L. 2013. "Housing finance and monetary policy''. Journal of the European Economic Association, 11: 101–122.

Cesa-Bianchi, A. 2013. "Housing cycles and macroeconomic fluctuations: A global perspective". Journal of International Money and Finance (2013), 37: 215–238.

Edvinsson, R.. 2005. Growth, Accumulation, Crisis: With New Macroeconomic Data for Sweden 1800-2000. Dissertation, Stockholm University.

-----------------. 2013a. “New Annual Estimates of Swedish GDP in 1800–2010”. The Economic History Review (2013), 66: 1101–1126.
-----------------. 2013b. “Swedish GDP 1620–1800: Stagnation or Growth?”. Cliometrica (2013), 7: 37–60.
-----------------. 2014. ‘The Gross Domestic Product of Sweden within present borders, 1620–2012’, in *Historical Monetary and Financial Statistics for Sweden, Volume II: House Prices, Stock Returns, National Accounts, and the Riksbank Balance Sheet, 1620–2012*. (eds. Rodney Edvinsson, Tor Jacobson and Daniel Waldenström). Sveriges Riksbank and Ekerlids.
Edvinsson, R. & Hegelund, E. 2016. “The business cycle in historical perspective: Reconstructing quarterly data on Swedish GDP 1913-2014”. Stockholm Papers in Economic History No. 18
Edvinsson, R., Ingman, G. & Eriksson, K. 2020. “A real estate price index for Stockholm, Sweden 1818–2018: putting the last decades housing price boom in a historical perspective”. Scandinavian Economic History Review.
Edvinsson, R. & Söderberg, J. 2010. “The evolution of Swedish consumer prices 1290–2008”, in *Historical Monetary and Financial Statistics for Sweden, Volume I: Exchange rates, prices, and wages, 1277–2008.* (eds. Rodney Edvinsson, Tor Jacobson and Daniel Waldenström) Sveriges Riksbank and Ekerlids.
Edvinsson, R. & Ögren, A. 2014. ‘Swedish money supply, 1620–2012’, in *Historical Monetary and Financial Statistics for Sweden, Volume II: House Prices, Stock Returns, National Accounts, and the Riksbank Balance Sheet, 1620–2012*. (eds. Rodney Edvinsson, Tor Jacobson and Daniel Waldenström). Sveriges Riksbank and Ekerlids.
Egert, B., & Mihaljek, D. 2007. “Determinants of house prices in Central and Eastern Europe. Comparative economic studies”. 49, 3: 367–388.
Engle, R. & Granger C. 1987. “Cointegration and Error Correction: Representation, Estimation, and Testing”. Econometrica, 55, 2: 251-276.
Englund, P., & Ioannides, Y.M. 1997. “House price dynamics: an international empirical perspective”. Journal of Housing Economics, 6, 2:119–136.
Englund, P. 2019. ”Skattereformen 1991 – hur lyckad blev den?” Ekonomisk Debatt.
Eklund, K. 2016. “En helhetspolitik mot bokrisen”. Ekonomisk Debatt.
Eriksson, K. 2021. “How Stockholm was Owned – Markets, Prices and Ownership”. Dissertation (*Forthcoming)*, Stockholm University.
Fregert, K. & Svensson, R. 2014. “Fiscal statistics for Sweden, 1670–2011”, in *Historical Monetary and Financial Statistics for Sweden, Volume II: House Prices, Stock Returns, National Accounts, and the Riksbank Balance Sheet, 1620–2012.* (eds. Rodney Edvinsson, Tor Jacobson and Daniel Waldenström). Sveriges Riksbank and Ekerlids.
Gerardi, K., Rosen, S. & Willen, P. 2010. “The Impact of Deregulation and Financial Innovation on Consumers: The Case of the Mortgage Market.” Journal of Finance 65 (1): 330–60
Goodhart, C. & Hofmann, B. 2007. “House Prices and the Macroeconomy: Implications for Banking and Price Stability”. Oxford University Press, Oxford
Gonzalo, J. 1994. Five alternative methods of estimating long-run equilibrium relationships. Journal of Econometrics 60: 203–233.
Greenspan, A., & J. Kennedy. 2008. “Sources and Uses of Equity Extracted from Homes.” Oxford Review of Economic Policy 24, 1: 120–44.
Hofmann, B. 2003. “Bank lending and property prices: some international evidence”. Technical Report 22, The Hong Kong Institute for Monetary Research.
Hofmann, B. 2004. “The determinants of private sector credit in industrialized countries: do property prices matter?” International Finance 7: 203–234.

Holly, S., & Jones, N. 1997. “House prices since the 1940s cointegration, demography and asymmetries”. Economic Modelling, 14, 4: 549–565.
Herold, T. 2019. “I andra hand – om hyresregleringens förlorare”. Tankesmedjan Timbro, Stockholm.
Iacoviello, M. 2005. “House Prices, Borrowing Constraints, and Monetary Policy in the Business Cycle.” American Economic Review, 95, 3: 739–64.
Iacoviello, M., & S. Neri. 2010. “Housing Market Spillovers: Evidence from an Estimated DSGE Model.” American Economic Journal: Macroeconomics 2, 2: 125–64.
Jacobsson, E. 1996. ”Och Mödan Gav Sin Lön: Om Bostadspolitik Och Bostadskooperation i Stockholm 1870–1930”. Stockholm University, The Department of Economic History.
Johansen, S. 1995. *Likelihood-Based Inference in Cointegrated Vector Autoregressive Models*. Oxford University Press.
Kepili, E. 2020. “The Impact of Macroeconomic Factors on the House Prices during Liberalisation”. Jurnal Ekonomi Malaysia 54, 2: 1-12
Kishor, K. & Marfatia, H. 2016. “The Dynamic Relationship Between Housing Prices and the Macroeconomy: Evidence from OECD Countries”. J Real Estate Finan Econ (2017) 54: 237–268
Kiyotaki, N., & J. Moore. 1997. “Credit Cycles.” Journal of Political Economy 105 (2): 211–48.
Kopsch, F. 2019. ”En hyresmarknad i kris : fortsätt lindra symptomen eller bota sjukdomen?” SNS förlag, Stockholm.
Kopsch, F. 2021. ”Hyresregleringens prislapp” Tankesmedjan Timbro, Stockholm.
Lind, H. & Lundström, S. 2011. ”Kommersiella Fastigheter i Samhällsbyggandet”. Stockholm: SNS förlag.
Lind, H. 2016. ”Varför byggs det inte mer? En översikt av tänkbara incitamentsproblem”. Ekonomisk Debatt.
Lindbeck, A. 2016. ”Hur avveckla hyreskontrollen?” Ekonomisk Debatt.
Meen, G. 2001. “Modelling Spatial Housing Markets: Theory, Analysis and Policy”. Kluwer Academic Publishers.
Miles, D. 1992. “Housing Markets, Consumption and Financial Liberalisation in the Major Economies.” European Economic Review, 36, 5: 1093–1136.
Muellbauer, J. & Murphy, A. 2008. “Housing Markets and the Economy: The Assessment”. Oxford Review of Economic Policy, 24, 1: 1–33
Nneji, O., Brooks, C. & Ward, C. 2013. “House price dynamics and their reaction to macroeconomic changes.” Economic Modelling (2013), 32: 172–178
Oikarinen, E. 2009. “Interaction between housing prices and household borrowing: the Finnish case”. Journal of Banking and Finance 33, 747-756.
Poterba, J.M. 1984. “Tax Subsidies to Owner-Occupied Housing: An Asset-Market Approach”. The Quarterly Journal of Economics, 99, 4: 729-752.
Rajan, R. & Zingales, L. 1998. “Financial Dependence and Growth”. The American Economic Review, 88, 3: 559-586.
Statistiska centralbyrån (SCB). Statistikdatabasen: *Folkmängd efter ålder och år*. 1800-2020. Retrieved on 2021-04-12.
Statistiska centralbyrån (SCB). Statistikdatabasen: *Faktorprisindex för byggnader (FPI)*. 1910-2020. Retrieved on 2021-03-30.
Stock, J. & Watson, M. W. 2003. “Has the Business Cycle Changed and Why?” NBER Macroeconomics Annual 2002 17: 159–218
Sveriges Riksbank. 1931. ”Sveriges Riksbank 1668-1918-1924*”*, band V.
Söderberg, J., Blöndal, S. & Edvinsson, R. 2014. ‘A price index for residential property in Stockholm, 1875–2011’, in *Historical Monetary and Financial Statistics for Sweden,*

Volume II: House Prices, Stock Returns, National Accounts, and the Riksbank Balance Sheet, 1620–2012. (eds. Rodney Edvinsson, Tor Jacobson and Daniel Waldenström). Sveriges Riksbank and Ekerlids.

Waldenström, D. 2014. 'Swedish stock and bond returns, 1856–2012', in *Historical Monetary and Financial Statistics for Sweden, Volume II: House Prices, Stock Returns, National Accounts, and the Riksbank Balance Sheet, 1620–2012.* (eds. Rodney Edvinsson, Tor Jacobson and Daniel Waldenström). Sveriges Riksbank and Ekerlids.

Appendix

A1: Robustness of results

The robustness of the results in 7.1 are tested by employing real mortgage debt in place of real total debt. As in the main analysis, exogeneity of $\boldsymbol{DEM}$ is assumed. The choice of lag-length is very similar to that of the main analysis, and as emphasis is put on the most parsimonous information criteria, one lag is chosen according to SBIC. Johansen's Trace test indicates that for both Stockholm and Gothenburg, there is at most one cointegrated relationship; see table A1:1.

Table A1:1. Johansen's Trace test for cointegration with p=1 lags.

Cointegrating relationships	**r = 0**	**r ≤ 1**	**r ≤ 2**
1% Critical value	**76.07**	**54.46**	**35.65**
Stockholm with $\boldsymbol{D^M}$	87.35	36.14*	10.90
Gothenburg with $\boldsymbol{D^M}$	87.57	27.44*	13.72

The long-run relationship is presented in table A1:2 and the short-run dynamics in table A1:3. The long-run relationship is more sensible without$\boldsymbol{Y}$ – when included in the long-run relation, there is evidence of mutlicollinearity between$\boldsymbol{Y}$ and $\boldsymbol{D^M}$**.** The LR restriction of the exclusion of $\boldsymbol{Y}$ can neither be rejected on any conventional significance level. Overall, both models fit well, are statistically significant on the one percent level and show the correct signs. The effect of $\boldsymbol{D^M}$ on

$\boldsymbol{HPI^i}$ is smaller than that of $\boldsymbol{D^{TOT}}$, which highlights the importance of smaller consumption loans and down-payments on the dynamics of $\boldsymbol{HPI^i}$. On the other hand, both $\boldsymbol{R}$ and $\boldsymbol{CCI}$ are noticeably larger compared to the results in the main analysis.

While the speed of adjustment towards equilibrium is slower overall for each variable, the direction of adjustment is the same as in the main analysis. The sluggishness of the adjustment speed of $\boldsymbol{HPI^i}$ is more prevalent, where $\boldsymbol{HPI^i}$ adjusts by 3.08 and 6.41 percent annually in Stockholm and Gothenburg respectively. The oddity of the sign of $\boldsymbol{\Delta Y}$ is also uncovered, suggesting that the assumption of weak exogeneity of $\boldsymbol{\Delta Y}$ might be appropriate. The speed of adjustment of $\boldsymbol{\Delta R}$ is almost half of that in the main analysis.

The overall result does seem to give credence to the specifications in the main analysis. The overall model fit, while yielding lower log-likelyhood values, gives no cause for concern. When using $\boldsymbol{D^M}$, the model still lands in the same approximative range as when using $\boldsymbol{D^{TOT}}$.

Table A1:2. Estimated long-run $\boldsymbol{\beta}$ coefficients of house prices with total private debt between 1910 to 2020.

	HPI^i	Y	D^M	R	CCI	Constant
Stockholm	1	0	-0.6824*** (0.1753)	0.2804*** (0.0362)	4.0425*** (0.9183)	-2.9662
Gothenburg	1	0	-0.5388*** (0.1153)	0.1933*** (0.0239)	2.1727** (0.6037)	-2.1965

P-value for exclusion of Y for Stockholm = 0. 0.346, ---..--- for Gothenburg = 0.419.
*, **, *** indicate p ≤ 10%, p ≤ 5% and p ≤ 1% significance, respectively. Standard error in parenthesis. The null-hypothesis of the LR test of identifying restrictions is that exclusion is assumed.

Table A1:3. The estimated adjustment coefficients $\boldsymbol{\alpha}$ of house prices and underlying variables between 1910 to 2020.

	α^{Sthlm}	α^{Gbg}
ΔHPI^i	-0.0308** (0.0152)	-0.06406*** (0.0222)
ΔY	-0.0378*** (0.0060)	-0.0560*** (0.0084)
ΔD^M	0.0475*** (0.0140)	0.0694*** (0.0200)
ΔR	-0.4182** (0.2930)	-0.5477** (0.2388)
ΔCCI	-0.0189*** (0.0066)	-0.0255*** (0.0095)
Log likelyhood	582.09	586.52
AIC	-9.98	-10.06
HQIC	-9.65	-9.74
SBIC	-9.17	-9.25
χ^2	31.62	30.03
JB test	0.00	0.00
Skewness	0.02	0.00
Kurtosis	0.00	0.00
Stability	Yes	Yes
Stationarity CE	-3.173**	-2.976**
Stationarity $\boldsymbol{\varepsilon_t}$	-7.136***	-8.660***
LM test P = 1	0.36	0.1070
LM test P = 2	0.45	0.2171
LM test. P = 3	0.78	0.2232
LM test. P = 4	0.22	0.5814

χ^2 are given for ΔHPI^i. The JB test is the Jarque-Berra goodness-of-fit-test. The LM test is the Lagrange-Multiplier test for serial correlation in the residuals. The JB test is the Jarque-Berra goodness-of-fit-test. Stability implies that all eigenvalues are within the unit circle. Stationarity of the cointegration equation (CE) and the residual of the error-correction model ε_t are the ADF-test statistics with a no trend-specification. *, **, *** indicate p ≤ 10%, p ≤ 5% and p ≤ 1% significance, respectively. Standard error in parenthesis.

A2: Data series and complimentary sources

Variable	**Source**	**Period covered**	**Complimentary data**
House Price Indices	Söderberg et al. (2014) Bohlin (2014) Edvinsson et al. (2020)	1818-1875 1875-1957 1957-2012 2012-2020*	**[1],[2]**
Consumer Price Index	Edvinsson & Söderberg (2010)	1818-2012 2012-2020*	**[5]**
Gross Domestic Product	Edvinsson (2013a, 2013b, 2014)	1818-2013 2014-2020*	**[3]**
Private Credit	Ahnland (2015)	1900-2013 2014-2020*	**[4]**
Interest Rates	Sveriges Riksbank.	1856-2002 2002-2020*	**[6]**
Construction Cost Index	Statistiska centralbyrån	1910-2020	**.**
Total Immigration	Statistiska centralbyrån	1875-2020	**.**

*Indicates period filled in with complimentary data.

Complimentary data sources

Statistiska centralbyrån (SCB). Statistikdatabasen*: Boende, byggande och bebyggelse*. Sent by email upon request. **[1]**

Statistiska centralbyrån (SCB). Statistikdatabasen*: Fastighetsprisindex för permanenta småhus, 1990=100 efter län och år*. 2012-2020. Retrieved on 2021-03-30. **[2]**

Statistiska centralbyrån (SCB). Statistikdatabasen*: GDP: (ESA 2010) Expenditure approach*. 2013-2020. Retrieved on 2021-03-30. **[3]**

Statistiska centralbyrån (SCB). Statistikdatabasen*: Finansräkenskaper efter sektor, kontopost och motsektor (ENS2010). År 1995 – 2020*: 2014-2020. Retrieved on 2021-03-30. **[4]**

Statistiska centralbyrån (SCB). Statistikdatabasen*: Konsumentprisindex, 1980=100.* 2014-2020. Retrieved on 2021-03-30. **[5]**

Sveriges Riksbank. Referensräntan. Retrieved on 2021-04-15. **[6]**

A3: Augmented Dickey-Fuller (ADF), Phillips-Perron and DF-GLS test results

ADF test results

Variable	Test statistic I(0)	Test statistic I(1)	1%	5%	10%
HPI^{STHLM}	-0.524	-7.593*	-4.025	-3.444	-3.144
HPI^{GBG}	-0.447	-10.805*	-4.025	-3.444	-3.144
Y	-2.182	-10.689*	-4.025	-3.444	-3.144
D^{TOT}	-1.924	-13.417*	-4.025	-3.444	-3.144
D^{M}	-1.817	-5.939*	-4.033	-3.447	-3.147
R	-1.858	-11.889*	-4.033	-3.447	-3.147
CCI	-2.577	-12.623*	-4.037	-3.449	-3.149
DEM	-3.014	-9.317*	-4.033	-3.447	-3.147

*Indicates order of integration on at least the 5% level. Tests were conducted with a constant and trend.

Phillips-Perron test results

Variable	Test statistic I(0)	Test statistic I(1)	1%	5%	10%
HPI^{STHLM}	-1.042	-7.193*	-4.033	-3.447	-3.147
HPI^{GBG}	-1.202	-9.121*	-4.033	-3.447	-3.147
Y	-1.617	-9.599*	-4.033	-3.447	-3.147
D^{TOT}	-1.159	-7.372*	-4.033	-3.447	-3.147
D^{M}	-2.597	-5.940*	-4.033	-3.447	-3.147
R	-1.622	-11.088*	-4.033	-3.447	-3.147
CCI	-2.450	-12.662*	-4.037	-3.449	-3.149
DEM	-3.029	-8.097*	-4.033	-3.447	-3.147

*Indicates order of integration on at least the 5% level. Tests were conducted with a linear time trend.

DG-GLS test results

Variable	p = 1	p = 4	1%	5%	10%
HPI^{STHLM}	-1.427	-0.896	-3.555	-2.992	-2.702
HPI^{GBG}	-1.065	-1.200	-3.555	-2.992	-2.702
Y	-1.445	-1.464	-3.555	-2.992	-2.702
D^{TOT}	-1.603	-1.712	-3.555	-2.992	-2.702
D^{M}	-2.914	-2.844	-3.555	-2.992	-2.702
R	-1.981	-1.282	-3.555	-2.992	-2.702
CCI	-1.607	-1.718	-3.567	-3.006	-2.715
DEM	-3.286*	-2.074	-3.525	-2.966	-2.677

Significance levels are given for p = 1. *Indicates integration on the 5% level.

A4: Lag-Length Selection, and Johansen's Trace test for short-run parameters for utilizing Wald tests

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-8.19718				1.3e-06	.620508	.873669	1.245
1	649.808	1316	25	0.000	9.3e-12	-11.2114	-10.705	-9.96238*
2	691.61	83.604	25	0.000	6.9e-12	-11.5254	-10.7659	-9.65194
3	733.783	84.346*	25	0.000	5.0e-12*	-11.8464*	-10.8338*	-9.34844
4	746.483	25.4	25	0.440	6.5e	12	-11.6165	-10.3507

Maximal lag-length: 4 Time period: 1914-2020
Endogenous: HPI^{STHLM}, Y, D^{TOT}, R, CCI
Exogenous: DEM, dummyww1, dummyww2, dummymid80s, _cons

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-3.84975				1.2e-06	.539248	.792409	1.16374
1	638.049	1283.8	25	0.000	1.2e-11	-10.9916	-10.4852*	-9.74258*
2	674.254	72.41	25	0.000	9.5e-12	-11.201	-10.4415	-9.32753
3	711.253	73.999*	25	0.000	7.7e-12*	-11.4253*	-10.4127	-8.92733
4	726.28	30.054	25	0.222	9.5e-12	-11.2389	-9.97308	-8.11642

Maximal lag-length: 4 Time period: 1914-2020
Endogenous: HPI^{GBG}, Y, D^{TOT}, R, CCI
Exogenous: DEM, dummyww1, dummyww2, dummymid80s, _cons

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	79.8857				1.1e-07	-1.81472	-1.55253	-1.15119
1	420.705	681.64	25	0.000	7.9e-12	-11.385	-10.7951	-9.89206*
2	456.648	71.886	25	0.000	5.8e-12	-11.7166	-10.7989*	-9.39425
3	486.155	59.014	25	0.000	5.3e-12*	-11.8532*	-10.6078	-8.70141
4	507.296	42.281*	25	0.017	6.6e-12	-11.7362	-10.1631	-7.75505

Maximal lag-length: 4 Time period: 1914-2020
Endogenous: HPI^{STHLM}, Y, D^{TOT}, R, CCI
Exogenous: DEM, dummyww1, dummyww2, _cons

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	143.232				1.3e-09	-6.25521	-6.02693	-5.6283
1	351.896	417.33	25	0.000	1.7e-13	-15.2144	-14.6057*	-13.5427*

2	378.736	53.679	25	0.001	1.7e-13	-15.3042	-14.3149	-12.5875
3	414.878	72.284	25	0.000	1.2e-13	-15.8477	-14.478	-12.0862
4	450.282	70.808*	25	0.000	1.1e-13*	-16.3552*	-14.605	-11.5488

Maximal lag-length: 4 Time period: 1980-2020
Endogenous: HPI^{STHLM}, Y, D^{TOT}, R, CCI
Exogenous: DEM, dummymid80s, _cons

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	82.3649				1.0e-07	-1.88984	-1.62765	-1.22631
1	401.639	638.55	25	0.000	1.4e-11	-10.8072	-10.2173*	-9.31428*
2	436.322	69.367	25	0.000	1.1e-11	-11.1007	-10.183	-8.77831
3	466.826	61.009	25	0.000	9.6e-12*	-11.2675	-10.0221	-8.11569
4	494.328	55.002*	25	0.000	9.7e-12	-11.3433*	-9.7701	-7.36207

Maximal lag-length: 4 Time period: 1914-2020
Endogenous: HPI^{GBG}, Y, D^{TOT}, R, CCI
Exogenous: DEM, dummyww1, dummyww2, _cons

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	150.205				9.4e-10	-6.59536	-6.36707	-5.96845
1	360.237	420.06	25	0.000	1.2e-13	-15.6213	-15.0126*	-13.9496*
2	391.818	63.161	25	0.000	9.2e-14*	-15.9423	-14.9531	-13.2257
3	411.468	39.3	25	0.034	1.5e-13	-15.6814	-14.3116	-11.9199
4	446.766	70.597*	25	0.000	1.3e-13	-16.1837*	-14.4335	-11.3774

Maximal lag-length: 4 Time period: 1980-2020
Endogenous: HPI^{GBG}, Y, D^{TOT}, R, CCI
Exogenous: DEM, dummymid80s, _cons

1910 to 1979

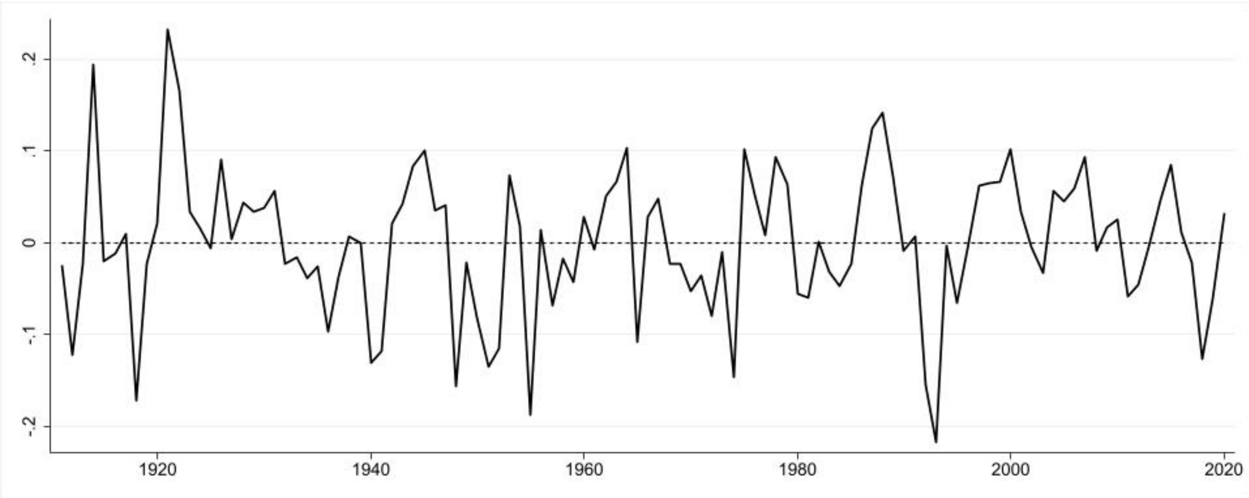
Cointegrating relationships	**r = 0**	**r ≤ 1**	**r ≤ 2**
1% Critical value	**76.07**	**54.46**	**35.65**
Stockholm with $\boldsymbol{D^{TOT}}$	94.64	53.66*	16.82
Gothenburg with $\boldsymbol{D^{TOT}}$	81.80	47.20*	18.89

1980 to 2020

Cointegrating relationships	r = 0	r ≤ 1	r ≤ 2
1% Critical value	**76.07**	**54.46**	**35.65**
Stockholm with $\boldsymbol{D^{TOT}}$	107.99	45.86*	20.17
Gothenburg with $\boldsymbol{D^{TOT}}$	113.63	47.19*	26.48

A5: Residuals of the error-correction models of Stockholm and Gothenburg

Stockholm



Gothenburg