



SCHOOL OF
ECONOMICS AND
MANAGEMENT

Money Matters

A time varying State Space approach to the relationship between inflation and money supply

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Abstract

This thesis investigates the time-varying relationship between inflation and money supply using a state space model. We use an extensive dataset with data over the years 1870-2023 and analyze the countries Sweden, the United States, and the United Kingdom. The results show that the link between money supply and inflation seems to depend on the underlying inflationary and monetary regime. During periods of higher inflation and unstable economic conditions, the link is stronger. Furthermore, we find a positive and increasing relationship between money supply and housing prices. During periods when the link between CPI and money supply is at historically weak levels, the link between money supply and housing prices is at historically strong levels. Money growth may thus manifest in asset price inflation.

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Contents

1	Introduction	4
2	Theory and Literature	6
2.1	Quantity Theory of Money	6
2.2	Empirical literature	7
3	Background	10
3.1	Monetary history: Sweden	10
3.2	Monetary history: The United Kingdom	11
3.3	Monetary history: The United States	12
4	Data	14
4.1	A model with CPI	14
4.2	A model with housing prices	16
5	Method	19
5.1	The State Space Approach	19
5.2	A model with CPI	20
5.3	A model with housing prices	21
6	Results and discussion	23
6.1	CPI-model	23
6.1.1	Sweden	24
6.1.2	The United Kingdom	26
6.1.3	The United States	28
6.2	Housing price-model	30
6.2.1	Sweden	31
6.2.2	The United Kingdom	32
6.2.3	The United States	33
7	Conclusion	34
	References	35
A	State space estimates	40

1

Introduction

The question of money supply and how it is correlated with inflation has puzzled researchers for hundreds of years. In an essay from as early as the year 1752, David Hume discusses the consequences of an increased monetary stock ([Hume \(1752\)](#)). [Friedman and Schwartz \(1963\)](#) further explores the monetary reasoning in Hume's essay conducting a statistical examination of the United States between 1867 and 1960. [Friedman and Schwartz \(1963\)](#) argues that changes in money stock are closely related to other key macroeconomic variables.

What effects monetary policy and central bank interventions have on the real economy have been highly debated among researchers and policymakers in recent years. Different views exist regarding the nature of these relationships. Some researchers point towards the correlation being non-existing while others claim that there exists a one-to-one relationship between the two variables, i.e. that an increase in money supply directly increases inflation.

[Estrella and Mishkin \(1997\)](#) find evidence that the money supply has lost its relevance as an inflation indicator. Other researchers find a strong long-run relationship between inflation and monetary aggregates ([Benati \(2021\)](#)) as well as evidence of a lagged effect of monetary aggregates on inflation, and that the relationship is found by averaging the time periods of money supply and inflation ([Fitzgerald \(1999\)](#)).

The results in the empirical research are not necessarily contradicting, but there is no clear consensus. The one conclusion that can be drawn is that they all may be right about the relationship, at different time periods. The research showing the non-existing relationship between money supply and inflation usually analyses a shorter period of time and specifically periods of low and stable inflation (see for example [Estrella and Mishkin \(1997\)](#)) while the research showing a strong link analyzes longer periods including periods of high inflation (see for example [Christiano and Fitzgerald \(2003\)](#) and [Dwyer Jr. and Hafer \(1988\)](#)).

One might suspect that increased globalization and liberalization of the economy make inflation less responsive to changes in the monetary aggregates and therefore that the relationship between money supply and inflation not only weakens but also lags in a time-varying perspective. Other causes for a weaker relation might be a result of Central Banks increasing the effort to stabilize inflation which has led to monetary flow into assets such as real estate. ([Gertler and Hoffmann \(2018\)](#)).

In this thesis, we aim to analyze the time-varying relationship between inflation and the money supply. We conduct analysis on two main questions. Firstly, we want to analyze how the relationship between consumer price inflation (CPI) and

money supply emerges over time. Secondly, we want to identify whether there exist other measures of price levels that show a different relationship with money supply. Here, we conduct an analysis on a housing price index and its link to money supply. We use a dataset covering the years 1870-2023 and investigate the United Kingdom, the United States, and Sweden country by country on which we apply a state space model that allows the relationship to be time-varying.

Our results conclude that the link between money supply and consumer prices is time-varying, and depends on the underlying economic conditions such as inflation rate and monetary regime. Furthermore, we see that the link between housing prices and money supply is indeed positive. This relationship is time-varying and increasing for the United Kingdom and Sweden but appears to be constant in our model for the United States. Furthermore, one of our main findings is that during the past 30 years, the link between money supply and CPI has been at historically low levels. During the same period, the link between money supply and housing prices is at historically high levels. We can thus suspect that an increased money supply may manifest in increased asset prices rather than in CPI, potentially due to financial liberalization and financial innovations leading to a lower proportion of the money stock being spent on the real economy.

The first section of this paper provides a brief background and problem formulation. In Section 2 we conduct a literature review of the existing research related to the relationship between money supply and inflation, using both empirical and theoretical literature. In section 3, we provide a brief historical background of the monetary policy conducted in the three countries over the time period. In section 4, we give a description of the dataset being used as well as an analysis of the main model variables: Real GDP, CPI, housing prices, and money supply. Furthermore, section 5 provides a description of the econometric approach State Space Model and our statistical specification. In section 6, we present our empirical results as well as a discussion regarding these based on history and empirical literature. Lastly, section 7 provides concluding remarks.

2

Theory and Literature

The literature on money supply and inflation is comprehensive and there exist both theoretical and empirical approaches to the question. Our analysis lies in the intersection of the effects of the money supply on economic factors and explanations for the link between money supply and prices over time.

In section 2.1, we will present a theoretical model, the quantity theory of money. In section 2.2 we focus on summarizing the empirical literature studying the link between inflation and money supply. Here we give a description of the literature investigating the inflation regime and monetary regime in relation to the link between inflation and money supply. We further give a description of the literature investigating the effect of monetary expansions on asset prices.

2.1 Quantity Theory of Money

The quantity theory of money states that changes in money supply growth are followed by equal changes in the inflation rate and in the end, through the Fisher equation, in real interest rates. More specifically, the theory measures the extent to which inflation movements can be explained by purely monetary forces. ([De Grauwe and Polan \(2005\)](#)). In non-growth terms, the relation can be written as:

$$MV = PY \tag{2.1}$$

Where M is money supply, V is velocity, Y is real output and P is price level. In growth terms, the relationship can be written as:

$$m + v = y + p \tag{2.2}$$

Therefore, solving for p gives us an expression for the growth of prices in terms of the growth of money supply, velocity, and output:

$$p = m - y + v \tag{2.3}$$

The theory is based on two main assumptions. Firstly, a proportional relation exists between inflation and the growth rate of money. Thinking of it as a regression of money growth and inflation, the coefficient of money is supposed to be equal to 1. That is, a permanent increase in money growth results in an equal increase of the inflation rate in the long run. Secondly, over a sufficiently long period of time, output and velocity changes orthogonal to the growth of the money stock. This

means that a permanent increase in the growth rate of money has no effect on output and velocity in the long run.

2.2 Empirical literature

Money supply in relation to prices and inflation has gradually lost relevance in monetary policy decision-making, as well as in research. There exists some empirical evidence against the quantity theory of money over the years 1985-2010. One explanation may be that the new monetary policy rules adopted by central banks worldwide respond effectively to inflationary pressure and prevent monetary growth from spilling over onto inflation (Sargent and Surico (2011)). Papadia and Cadamuro (2021) further confirms these results, and concludes that as an effect of the inflation being at around the inflation target during the last two decades, the link between money and inflation has been weak. Earlier empirical studies also show that the monetary aggregates act poorly as an information variable when conducting macroeconomic analysis, and therefore should not be used for monetary policy decision-making in general (Estrella and Mishkin (1997)). However, analyzing the Eurosystem, Gerlach and Svensson (2011) finds that the real money supply gap seems to be a fairly good predictor of future inflation.

One of the reasons why the link between money supply and inflation has weakened during recent years is the low inflation period. That is a period lasting from the 1970s throughout the pre-covid-pandemic years. During this period, the monetary regime shifted and monetary targeting was adopted by central banks worldwide (Borio et al. (2023)). Borio et al. (2023) further finds a one-to-one relationship between money supply and inflation. However, the results only show signs of this relationship during periods of high inflation. In other words, this study shows that the relationship between money supply and inflation depends on the underlying inflation regime. Estrella and Mishkin (1997) use a period with relative price stability in their research, using a sample from the time period 1979-1995, thus confirming the hypothesis that the link weakens during periods of low and stable inflation. Similar results as Borio et al. (2023) have been obtained by De Grauwe and Polan (2005) who analyze the money supply, the quantitative theory of money, and its effect on long-run growth. The results show a strong and positive relationship between the long-run growth rate of money and inflation considering the full sample of all countries. However, by splitting the sample of countries and distinguishing low-inflation countries from high-inflation countries, the relationship disappears. The conclusion that monetary aggregates act poorly as an indicator of inflation during low inflation regimes is further supported by De Fiore et al. (2022) who conclude that standard models of inflation in general perform worse during inflation regime transitions, i.e. when low inflation is transitioning to high inflation or vice versa. This, the authors argue, is due to the fairly simple fact that the underlying indicators are changing.

Not only the inflationary regime could affect the link between inflation and money supply, but also the underlying monetary regime. Rolnick and Weber (2011) investigates the period when most countries had commodity standards as monetary regime (before the 1930s) with the period after when most countries changed to fiat standards. The results show that the growth rate of money has a higher correlation with inflation under fiat standards as compared to commodity standards. Despite this, Benati (2021) finds no compelling evidence of the link depending on the underlying

monetary regime. This research shows a one-to-one relationship between money growth and inflation over most of the 1800s until the 2010s.

There is in general an extensive amount of research concluding that the link between money supply and inflation seem to have weakened over time, yet it is important to consider the differences between the long and the short run. [Christiano and Fitzgerald \(2003\)](#) find a significant shift in the relationship between money supply and inflation comparing the period before and after the year 1960. During the early period, the results shows that the link between the two variables is strong and positive. However, during the later period, the link is weak and even turns negative under certain conditions. The research results differ comparing the short run with the long run. Analyzing shorter periods of time and estimating the short-run linkage between the growth rate of money and price level, [Dwyer Jr. and Hafer \(1988\)](#) shows that the link is very weak and almost invisible. Nonetheless, [Dwyer Jr. and Hafer \(1988\)](#) find that the long-run relationship remains strong and follows the Quantity Theory of Money. The long-run relationship between the money supply and inflation is further confirmed by [Fitzgerald \(1999\)](#). Averaging the data on two-years, four-years, and eight-years the author finds that the relationships increase with a larger averaging interval. The results also show that broader monetary measures, M2 and M3, give rise to a stronger relationship as compared to more narrow monetary measures.

These different views in the literature regarding the inflationary regime, monetary regime and the time period being investigated imply that the relationship between money growth, inflation, and the direction of money growth deserves more research. This in order to better understand the actual relationship and how it shifts over time, as well as for the reasons why the shift in the link happens.

With this in mind, the next question is why this shift in the link has happened in recent years, and why is it that the link only seems to exist under a high inflation regime? [Gertler and Hoffmann \(2018\)](#) provides us with some reasonable explanations. The authors argue that two main regime changes are particularly important explanations: financial liberalization and global disinflation.

The financial liberalization has resulted in new financial innovations, which [Gertler and Hoffmann \(2018\)](#) identify as important drivers of the shift in demand for money. This due to the fact that changed money demand is associated with a shift in money velocity weakening the empirical link between money growth and inflation. Additionally, more investments from financial institutions have likely gone into new financial instruments due to financial liberalization. These facts have likely affected monetary identities and led to money becoming a less accurate measure of financial conditions in general and inflationary pressure in particular. Furthermore, an increase in the share of bank credits seems to have gone into the real estate sector. One could therefore argue that there has been proportionally more credit (and money) flowing to the real estate sector as opposed to the real economy which then does not produce general price inflation but rather asset price inflation. Low and stable inflation regimes may thus have changed the way monetary expansions manifest. Instead of showing up as inflation, increased money supply may manifest in increased credit and asset prices ([Gertler and Hoffmann \(2018\)](#)). [Cechetti et al. \(2002\)](#) argues that asset prices can be a predictor of core inflation and that it is a variable that should be included in monetary policy decision-making. As total asset prices consist of different variables and it would be hard in practice to study them

all, [Goodhart \(2001\)](#) suggests using housing prices as a representative variable for assets overall.

[Gertler and Hoffmann \(2018\)](#) argues that there are several reasons for this shift in how inflation manifests. One of these explanations is that inflation being held down by anchored inflation expectations and global disinflation forces build up economic and financial imbalances which have a lesser impact on short-term inflation. When monetary policy is focused on short-term inflation development, as prescribed in standard inflation targeting frameworks, the policy will unintentionally accommodate the build-up of these imbalances and ultimately of future risk to financial stability.

Consumer price inflation is the generally used indicator of inflation for central bankers to use in decision-making. [Alchian and Klein \(1973\)](#) criticizes this and argues that CPI is statistically biased and only works in the short run. [Alchian and Klein \(1973\)](#) suggests that flexible prices should be included to incorporate the general well-being of an economy into the analysis. Assets are not typically included as variables in monetary decision-making. This is due to assets being highly volatile and incorporating expectations about the future which are hard and potentially impossible to calculate ([Goodhart \(2001\)](#)). However, a further important question that can be raised is whether growth in the money stock contributes to asset price inflation ([Schwartz \(2003\)](#)). The CPI clearly has some disadvantages and deserves to be questioned and alternative measures such as asset price inflation deserve to be discussed.

3

Background

The previous section indicates diversity in the conclusions regarding the time-varying relationship between money and inflation. However, much of the empirical literature emphasizes the importance of underlying economic conditions and monetary policy as well as inflation regime, inflation transitions, and length of time period. Thus, in this section, we will shortly discuss the economic conditions over time of each nation.

3.1 Monetary history: Sweden

In Sweden, the monetary period of 1870-2019 is characterized by six different monetary policy regimes; 1873-1914 Gold Standard, 1915-1931 On-Off Gold Standard, 1932-1951 Policy Innovation, 1952-1973 Bretton Woods System, 1974-1992 Full Employment Policy and 1993-2019 Norm Policy (Jonung (2019), Andersson (2023)).

At the beginning of our dataset, in 1875, Sweden was an underdeveloped country with, relative to this time period, well-developed institutions (Schön (2012)). One institution was the Swedish Central Bank, Riksbanken, which developed from a government-owned commercial bank to a consequential participant in the role of monetary policy (Andersson (2023)). Lindbeck (1973) however argues that the role of Riksbanken in the mid-1800s was modest and it was not until 1890 that Riksbanken actively engaged in the financial markets and interest rate policy. At that time, Sweden was bound by the Gold Standard system thus limiting Riksbankens ability to act (Andersson (2023), Lindbeck (1973)). However, in the time before and during the First World War, neutral Sweden with intact industries gained from the shortages and production problems in Europe following the war. This caused an inflow of money through increased exports and increased domestic military production which increased inflation causing Sweden to immediately leave the Gold Standard at the beginning of the First World War (Jonung (2019)). Sweden kept the ambition to return to the gold standard, which they did in 1924 (Jonung (2019), Andersson (2023)).

Critique against the gold standard gained attraction and Sweden left the Gold Standard in 1931 shortly after the United Kingdom declared departure from this arrangement (Jonung (1979), Jonung (2019)). The beginning of the 1930s was a time of policy innovation in Sweden, especially in terms of economic and monetary novelties. The main economic targets at this time were price stabilization and unemployment, which later developed into further regulations at the beginning of the

Second World War, especially towards capital. This was a lesson learned from the inflation-intensive period during the First World War ([Andersson \(2023\)](#), [Jonung \(2019\)](#)). [Lindbeck \(1973\)](#) argues that Swedish monetary policy changed postwar because of the increasing number of policy targets. Further, Lindbeck concludes that the extensive monetary policies together with government policies of market liberalization, decentralization, and re-distribution made Swedens economy characterized by both high inflation and high employment.

In 1951 Sweden joined the Bretton Woods System, thus the Swedish Krona was pegged to the USD, and Riksbanken controlled the interest rates and the capital flows, prioritizing the housing sector. The monetary and fiscal policy was closely tied at the time with an overall regulatory approach to the economy ([Jonung \(2019\)](#)).

Sweden left the Bretton Woods System in 1975. After leaving the Bretton Woods, the trust in economic governance remained, and extensive full employment policies came into action.

In an international context, Sweden was no exception to the deregulation and liberalization of markets that characterized the 1980s ([Andersson \(2023\)](#)). The full employment policy and the deregulation of domestic credit markets in the Novemberrevolution created a credit boom that eventually ended the fixed exchange rate policy due to high inflation and devaluation of the Swedish Krona ([Jonung \(2019\)](#)). However, the aftermath of the Swedish financial crisis in the 1990s meant new policy structures and new policy targets. The coordination between Riksbanken and the Swedish Government was abandoned and Riksbanken prioritized price stabilization as the main policy target ([Andersson \(2023\)](#)). Since the year 2000, Sweden and other European countries have experienced low inflation and low interest rates. However, some economists argue that the inflation targets are too complicated to monitor and implement in a dynamic economy, which imposes potential problems for the economy ([Svensson \(1996\)](#)).

3.2 Monetary history: The United Kingdom

The United Kingdom's situation during the 1800s was, compared to Sweden, different. The United Kingdom began to peg the sterling to gold as early as 1821, and their prominent economic role during this time caused several nations to follow this practice, among others Sweden, starting in the year 1870. The mainstream economic thinking at the time was to maintain a stable currency by pegging it to gold. An effect of this was that the Bank of England did not control the supply of money and rather relied on market forces to harmonize the money supply which was assumed to be stable against the gold ([Schenke \(2014\)](#)). This caused the Bank of England to frequently change the exchange rate in order to counteract monetary changes during the years 1880-1914.

In 1914, during the outbreak of WWI, the United Kingdom abandon the gold standard in the same manner and for the same reasons as Sweden, when experiencing high and persistent inflation fueled by the war ([Benati \(2006\)](#)). However, [Broadbent \(2020\)](#) points out that the International Gold Standard era and the Interwar era have been stable in terms of inflation. He further concludes that between these periods, the situation is very different in terms of inflation. Inflation is highly unstable when transitioning from one regime to another.

At the time, being an economic superpower with sterling as a well-integrated global currency caused capital outflows from the United Kingdom's economy resulting in deflation which [Pollard \(1985\)](#) argues marks the beginning of the decline of the British hegemony in an international trade context. The United Kingdom then continued to have a floating exchange rate with the US Dollar tied together with gold parity. After the economic turmoil in 1929-1931 and the sterling speculation, the United Kingdom abandoned this arrangement in 1931 ([Schenke \(2014\)](#), [Benati \(2006\)](#)). In the years following WWII the United Kingdom experienced economic hardships caused by the war-loan agreement with the United States., Bretton Woods, and economic conditions remaining after the war, which led the economic ideas towards control and regulations at the beginning of the 1970s ([Schenke \(2014\)](#)). [Broadbent \(2020\)](#) further concludes that between Bretton Woods and 1970-1992, the inflation increases were followed by declining numbers until right before 1992. Once again, inflation tends to be more volatile and increasing in the transitioning period. However, in 1992 the United Kingdom implemented the inflation target as the main monetary policy goal, which [Benati \(2006\)](#) argues launched the most stable macroeconomic era in British history.

3.3 Monetary history: The United States

The monetary history of the United States is similar to the one of both Sweden and the United Kingdom, due to the reason that many regime changes in monetary policy originate from the United States. The Federal Reserve System was implemented in 1914 after Congress passed the Federal Reserve Act. During the period before the Federal Reserve, the economy was generally more unstable. During the 1880-1920, prices were declining and the silver standard was questioned. Due to gold discoveries and the inflow of gold from Europe during the First World War, inflation increased rapidly, especially in the period of 1915-1920 ([Bredin and Fountas \(2018\)](#)).

After the war, the Federal Reserve implemented strict and contractionary monetary policy as a consequence of inflation during the WWI. This caused deflation in the years of 1920-1921 ([Bredin and Fountas \(2018\)](#), [Johanson \(1965\)](#)).

The 1930s were characterized by the Great Depression and the Federal Reserve conducted treasury management as monetary policy ([Johanson \(1965\)](#)). During the Great Depression, the money supply fell immensely as a consequence of the financial turbulence causing deflation in the years afterward ([Bredin and Fountas \(2018\)](#)). [Friedman and Schwartz \(1963\)](#) argues that the money supply in this period fell more than 25 percent.

The following years were characterized by the Second World War and post-war reconstructions ([Mankiw and Taylor \(2023\)](#)). During the war, money supply increased rapidly but inflation was temporarily kept stable through price regulations. This, however, only postponed the effect of increased money supply and resulted in inflation later. ([Bredin and Fountas \(2018\)](#)).

During the post-war period, 1948-1960, the monetary policy was revived as a whole. ([Johanson \(1965\)](#)). [Bredin and Fountas \(2018\)](#) suggests that the monetary policy norm in the 1950s was price stability. Nevertheless, the 1960s, especially the first half, was a time of monetary expansion in an attempt to stimulate the economy, thus increasing the money supply ([Nelson \(2007\)](#)).

During the early 1970s, the Bretton Woods system collapsed. This time was also characterized by the oil crisis which was followed by a recession in the early 1980s a boom in the later 1980s, and another recession in the early 1990s. However, during the 1980s the US simultaneously started to deregulate the banking system allowing financial institutions to trade globally and allowing for more banks and financial institutions to operate (Mankiw and Taylor (2020)) as well as for more financial innovations (Gertler and Hoffmann (2018)).

The 1990s and early 2000s were a period of relatively low inflation, high employment, and stable growth (Mankiw and Taylor (2023)) but with a dip in the economy in the early 2000s due to the dot-com bubble and 9/11. The events in the late 1990s to early 2000s meant that the Federal Reserve lowered interest rates and aimed to increase and maintain liquidity in the markets by increasing the money supply (Mankiw and Taylor (2020)). The financial crisis of 2007-2009 meant that interest rates increased in an attempt to curb demand. The growth rate of the economy fell and with that, the global production rate. (Mankiw and Taylor (2023)).

4

Data

In our analysis, we use the Jordà-Schularick-Taylor Macrohistory Database ([Òscar Jordà et al. \(2017\)](#)), a dataset that consists of annual data from 18 advanced economies with 48 real and nominal variables from the years 1870-2020.

We will be studying the United Kingdom, Sweden, and the United States using data from the entire period in order to investigate the relationship between CPI-inflation and money supply as well as the relationship between a housing price index and money supply.

Using data over 150 years we obtain data representing different economic and monetary regimes. We can thus distinguish institutional effects from pure economic ones, and see how the link between prices and money is related to the underlying monetary and inflationary regime.

The countries Sweden, the United Kingdom, and the United States are being chosen so that we can investigate the link between money supply and prices for countries with different economic conditions and draw conclusions on how certain underlying economic conditions affect the time-varying relationships. Sweden is a country with practically no power over the world market interest rate, while the United States is one of the main players with large influence over world economic conditions. The United Kingdom is in between Sweden and the United States considering world market power and has historically been a more important player as compared to today.

Thus, we will be able to investigate both different regimes and different economic conditions and analyze how these facts affect the link between the studied variables.

We will use two different models with two different measures of price levels in our analysis: CPI and a housing price index. Section 4.1 presents the data being used in the model with CPI and section 4.2 presents the data being used in the model with the housing price index.

4.1 A model with CPI

In our first analysis of the time-varying link between inflation and money supply, we use CPI as the variable for inflation. CPI is an index with base year of 1990, so 1990=100. Money Supply is defined as broad money, i.e. M2 and M3. Broad money is suggested to be used for measuring long-run effects between inflation and money supply by [Fitzgerald \(1999\)](#).

We use GDP as a control variable as it is reasonable to assume the growth rate of the economy affects underlying economic conditions. GDP is measured in real terms and is calculated as:

$$GDP_{real} = GDP_{nom}/CPI \quad (4.1)$$

Furthermore, we also use exports as a control variable which is assumed to have an impact on both inflation and money supply.

To capture the economic conditions past 2020, we complement the dataset for the CPI analysis with additional data up until 2023. Below is a description of the data sources for the additional years.

For Sweden, we use data from Statistiska Centralbyrån for the variables Money supply (SCB (2024b)), GDP (SCB (2024d)) and CPI (SCB (2024c)) over the years 2020-2023. Swedish export data comes from Statista and SCB (SCB (2024a), Statista (2023)). For the United States, GDP data comes from Bureau of Economic Analysis (2024), the money supply data comes from Federal Reserve Bank of St. Louis (2024), the export data from the International Monetary Fund (2024), and CPI data from U.S Bureau of Labor Statistics (2024). For the United Kingdom, GDP comes from Office for National Statistics (2024a), exports from the UK department for Business and Trade (2024), and money supply from the Bank of England (2024). Data on CPI for the United Kingdom comes from the Office for National Statistics (2024). The CPI data originally had an index with base year 2015. However, for comparison reasons we want the base year to be 1990 so that it fits with the data from Óscar Jordà et al. (2017). We thus recalculate the index to get base year 1990=100. By adding this data, we can conduct an analysis over the time period 1870-2023.

Inflation and CPI over the time period for the three different countries can be seen in Figures 3.1, 3.2, and 3.3. In the figures, all the variables are differentiated and logged to remove trends and achieve stationarity.

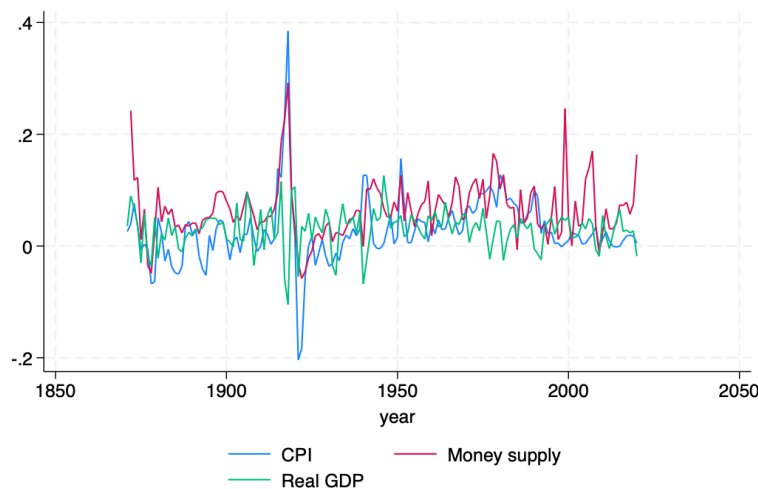


Figure 4.1: Sweden, CPI, Real GDP and Money supply, 1870-2023

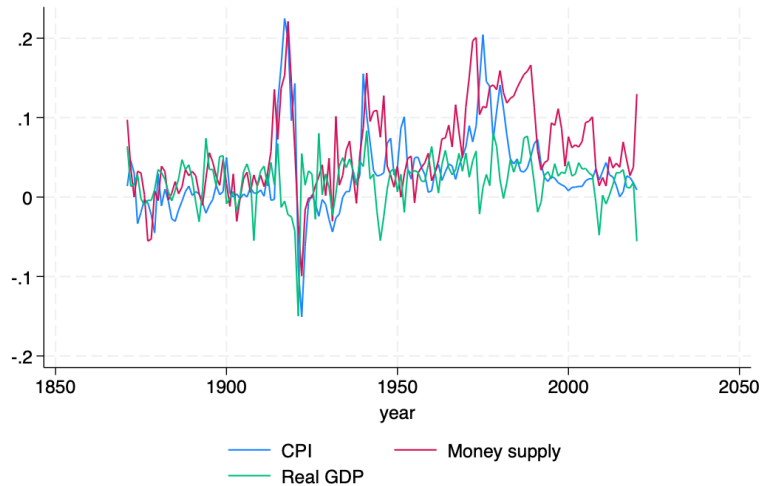


Figure 4.2: United Kingdom, CPI, Real GDP and Money supply, 1870-2023

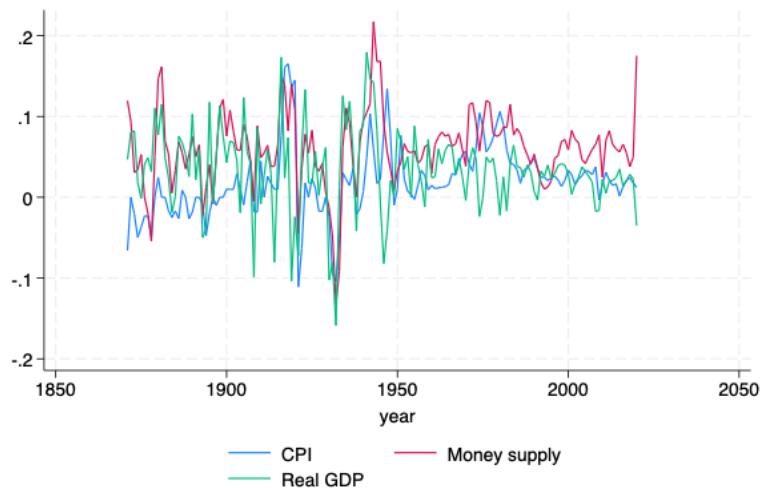


Figure 4.3: United States, CPI, Real GDP and Money supply, 1870-2023

The data seems to follow a similar pattern for all countries. There was a big peak in money supply and CPI around 1930. Overall, money supply seems to have followed inflation and GDP quite closely until the late 1900s. After the year 2000, it is clear for all countries that money supply has taken larger values than both CPI and GDP.

4.2 A model with housing prices

As an indicator for asset prices, the variable being used is a housing price index which we obtain from the same dataset as above. The dataset lacks data on the housing price index for the first 5 years for Sweden, the first 20 years for the US, and the first 29 years for the UK. We will thus be conducting the analysis over the following time periods for the different countries: Sweden year 1875-2020, the US years 1890-2020, and the UK years 1899-2020.

The housing price index is calculated in the following way (Knoll et al. (2014)):

$$\Delta P_T^h = \sum_{m=1}^M (w_t^m \Delta P_t^m) \quad (4.2)$$

Describing the aggregate house price change ΔP_T^h as an expression of the price change in the subsample m , ΔP_t^m , and the weight of subsample m , w_t^m .

Figures over the housing price index, Real GDP, and money supply are presented below in figure 4.4, 4.5 and 4.6. All variables are differentiated and logarithmized.

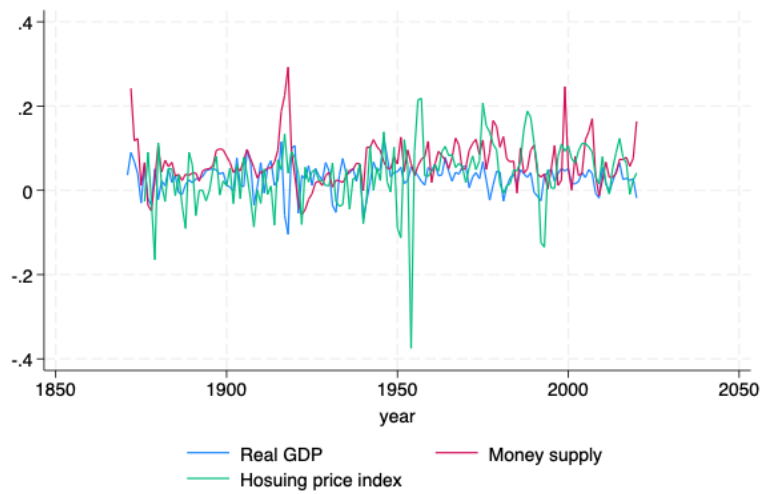


Figure 4.4: Sweden, housing prices, Real GDP and Money supply, 1875-2020

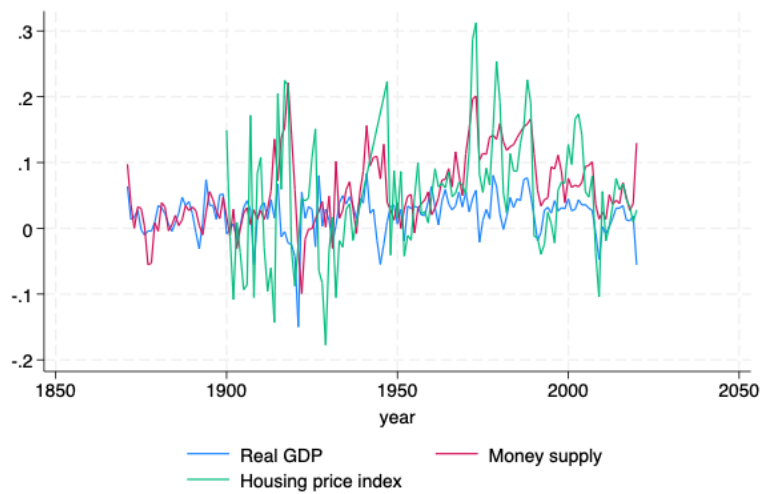


Figure 4.5: United Kingdom, housing prices, Real GDP and Money supply, 1899-2020

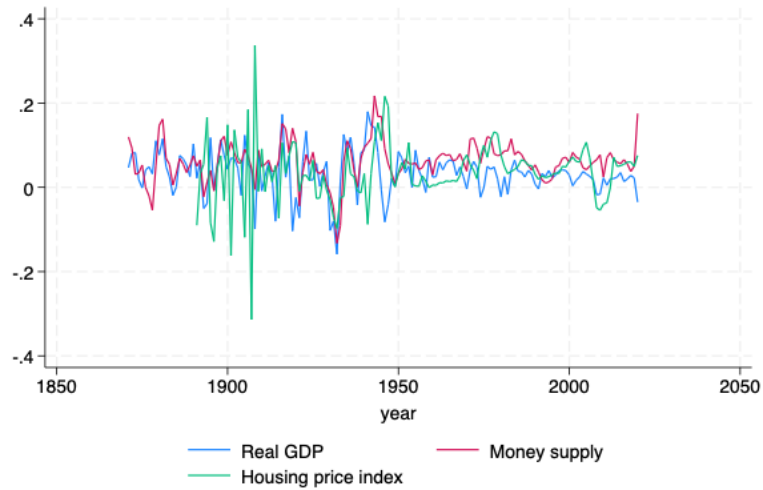


Figure 4.6: United States, housing prices, Real GDP and Money supply, 1890-2020

In similarity with the CPI figures, figure 4.1, 4.2 and 4.3, we see that there is reason to believe the housing price index is related to the money supply as the variation of housing prices seems to follow the money supply. However, it does not seem as strong for Sweden as it is for the United States and the United Kingdom.

5

Method

There has been a significant change in both the level and the variance of inflation over a longer time period. As sections 2, 3 and 4 make clear, the relationship between inflation and money supply has been unstable over time and is dependent on changes such as monetary policy and the current inflation rate. In other words, there have been structural changes highly affecting economic conditions and market behavior. It is difficult to fit a model under these conditions but these structural changes can be dealt with using a state space model (Simone (2000)).

Our baseline model is an OLS regression on which we apply a state space model with time-varying parameters. State space models applied to economics are mainly used in macroeconomics, specifically when analyzing inflation and GDP (see for example Kuzin (2006), Basdevant (2003), Pandher (2007), Kichian (1999)). A time-varying state space model captures the changes in the relationship between prices and money supply over time, a relationship we do not expect to be constant over time due to different macroeconomic factors and regimes.

We will be estimating the model country by country over the whole time period for the CPI analysis (1870-2023) and over the time periods described in section 4.2 for the housing price analysis.

5.1 The State Space Approach

A state space model captures the dynamics of an observed $n \times 1$ -vector Y_t in terms of a unobserved $r \times 1$ -vector α_t . The unobserved vector, α_t , is called the state vector and the observed vector is called the observation vector. The observation equation depicts how the observed vector is related to the unobserved state vector α_t (Hamilton (1994)).

When using a state space model, we can allow unobserved variables (state variables) to be incorporated into the observed model. That is, we can estimate unobserved relationships and variables. In our case, the unobserved variable is the link between inflation and money supply.

In our case, the state variables are described by a system of first-order difference equations. They depend on the values the variables had at any given time, and also depend externally on input variables. The state variables are, to its nature, dependent on their own previous values. (Hamilton (1994), Kim and Nelson (1989)).

Our state space models use a Kalman filter which is a recursive procedure for computing the optimal estimate of the state variables at time t based on the informa-

tion available at that time, consisting of all the observations up to and including Y_t (Mills (2019)). The unknown parameters are estimated using maximum likelihood.

We use a time-varying state space model. This way, we view the state equation as a time-varying parameterization of the intercept parameter α_t in the model (Teräsvirta et al. (2010)).

We start by running an OLS on the data. After that, we apply a state space model to the OLS output. However, a comment should be made regarding the OLS output and its reliability. As we are working with time series data, other regression models such as ARMA, ARCH and VAR should generally be used. Our main focus is therefore not on the OLS results, they mainly act as a benchmark for the state space model which we will present in the section 5.2 and 5.3. The OLS can be seen as an average of the state space outputs, and the state space model's main purpose is to show the relationship between money supply and inflation rather than showing how much in absolute values of the inflation variable could be explained by money supply.

5.2 A model with CPI

Our state space specification for country i at time t using CPI as dependent variable is presented in general as the system of equations represented by equations 5.1-5.3. The model for Sweden and the United Kingdom is presented in the system of equations represented by equations 5.4-5.6. Note that we take the first difference and the natural logarithm of all variables.

$$\Delta \ln(CPI_{i,t}) = \beta_0 + \beta_{1,i}\Delta \ln(X_{i,t}) + \beta_{2,i}\Delta \ln(RGDP_{i,t}) + \alpha_{1,i,t}\Delta \ln(MS_{i,t}) + \alpha_{2,i,t}\Delta \ln(MS_{i,t-1}) + \epsilon_{i,t} \quad (5.1)$$

$$\alpha_{1,i,t} = \alpha_{1,t-1} + \nu_t \quad (5.2)$$

$$\alpha_{2,i,t} = \alpha_{2,t-1} + \eta_t \quad (5.3)$$

With $\epsilon_t \sim iid(0,1)$, $\nu_t \sim iid(0,1)$ and $\eta_t \sim iid(0,1)$. We use consumer price inflation, $\Delta \ln(CPI_{i,t})$, as a dependent variable where CPI is an index with the year 1990=100. Exports, $\Delta \ln(X_{i,t})$, and Real GDP, $\Delta \ln(RGDP_{i,t})$, act as fixed coefficients and control variables. Money supply, $\Delta \ln(MS_{i,t})$, and lagged money supply, $\Delta \ln(MS_{i,t-1})$, are the time-varying parameters allowing for the relationship between CPI and inflation to vary over time. The money supply is defined as broad money supply, i.e. M2 and M3. The time-varying parameters are assumed to follow a random walk. We differentiate the variables in order to obtain stationarity and use natural logarithms for comparison purposes.

Equations 5.1-5.3 should be seen as a system of equations. Equation 5.1 is the observation equation where Y_t represents the matrix of output for CPI. Equation 5.2 and 5.3 are the state equations depicting that $\alpha_{1,i,t}$ and $\alpha_{2,i,t}$ are allowed to be time-varying. The state equations capture the dynamics of money supply and lagged money supply in relation to CPI.

It is reasonable to expect the money supply for the US to highly affect economic conditions and monetary policy decisions in both the UK and Sweden. We will thus include the US money supply, $\Delta \ln(MS_{US,t})$, as an additional fixed coefficient in the state space model for these two countries. The specification then takes the form represented by the system of equations 5.4-5.6.

$$\Delta \ln(CPI_{i,t}) = \beta_0 + \beta_{1,i} \Delta \ln(X_{i,t}) + \beta_{2,i} \Delta \ln(RGDP_{i,t}) + \beta_{3,i} \Delta \ln(MS_{US,t}) + \alpha_{1,i,t} \Delta \ln(MS_{i,t}) + \alpha_{2,i,t} \Delta \ln(MS_{i,t-1}) + \epsilon_{i,t} \quad (5.4)$$

$$\alpha_{1,i,t} = \alpha_{1,t-1} + \nu_t \quad (5.5)$$

$$\alpha_{2,i,t} = \alpha_{2,t-1} + \eta_t \quad (5.6)$$

With $\epsilon_t \sim iid(0, 1)$, $\nu_t \sim iid(0, 1)$ and $\eta_t \sim iid(0, 1)$. Equation 5.4 is the observation equation and equations 5.5 and 5.6 are the state equations. The equations can be interpreted the same way as for the general model in equations 5.1-5.6.

5.3 A model with housing prices

Using [Gertler and Hoffmann \(2018\)](#) as a starting point, we aim to investigate whether an explanation for the potentially weakening relationship between inflation and money supply can be explained by a surge in the relationship between asset price inflation and money supply. There exists evidence of the relationship between the money supply and inflation over a longer time period, and it seems unlikely that monetary expansions do not have an effect on prices.

We set up a similar model to the one for CPI, but instead use asset price inflation as the explanatory variable. As asset prices consist of a lot of different variables and it would be hard in practice to study them all, we will use housing prices as an indicator of asset prices, which is also recommended by [Goodhart \(2001\)](#). Using the same dataset as for the CPI analysis, we now instead use the housing price index (1990=100) variable.

We proceed in the same manner as for the CPI model, that is we start by estimating an OLS with the relevant variables and apply a state space model onto the OLS output using the OLS output as starting parameters. We exclude exports from this regression as it is not expected to affect housing prices to the same extent. Instead, we use long-term interest rate, LTRATE, as a control variable as it is reasonable to assume that the interest rate affects households' decisions to take a loan and therefore the probability of buying property.

Our new state space specification with the housing prices index for country i at time t is presented in equations 5.7 and 5.8. As for the CPI model, equations 5.7 and 5.8 should be seen as a system of equations.

$$\Delta \ln(HP_{i,t}) = \beta_0 + \beta_{1,i}\Delta \ln(RGDP_{i,t}) + \beta_{2,i}\Delta \ln(LTRATE_{i,t}) + \alpha_{1,i,t}\Delta \ln(MS_{i,t}) + \epsilon_{i,t} \quad (5.7)$$

$$\alpha_{1,i,t} = \alpha_{1,t-1} + \nu_t \quad (5.8)$$

With $\epsilon_t \sim iid(0, 1)$, $\nu_t \sim iid(0, 1)$.

Now, the house price index, $\Delta \ln(HP_{i,t})$, is the dependent variable and we have excluded exports. Furthermore, we have excluded lagged money supply and added long-term interest rate as a fixed coefficient. We now only have one state variable and thus only one state equation, $\alpha_{1,i,t}$ (equation 5.8). Equation 5.7 is the observation equation.

Otherwise, the specification is identical to the CPI model and the interpretation of the equations is the same as in section 5.2 .

For Sweden and the United Kingdom, we have also included the money supply of the United States as a control variable. The specification for these two countries is represented by the equation systems 5.9-5.10.

$$\Delta \ln(HP_{i,t}) = \beta_0 + \beta_{1,i}\Delta \ln(RGDP_{i,t}) + \beta_{2,i}\Delta \ln(LTRATE_{i,t}) + \beta_{3,i}\Delta \ln(MS_{US,t}) + \alpha_{1,i,t}\Delta \ln(MS_{i,t}) + \epsilon_{i,t} \quad (5.9)$$

$$\alpha_{1,i,t} = \alpha_{1,t-1} + \nu_t \quad (5.10)$$

With $\epsilon_t \sim iid(0, 1)$, $\nu_t \sim iid(0, 1)$.

6

Results and discussion

In this chapter we present OLS and State Space results by model. Section 6.1 contains the results for the model with CPI as inflation measure while section 6.2 contains the results for the model with the housing price index as price measure. Under each section, we also thoroughly discuss the results from a historical perspective of monetary and inflationary regime changes. We will analyze the state variables and how they are related to the different economic events presented in section 3.

6.1 CPI-model

We start by estimating a linear regression model using OLS. By doing so, we obtain starting values for the parameters we will estimate using a state space model in the next step.

The OLS output for the CPI-model is presented in table 6.1.

From Table 6.1, we see that the country where money supply seems to have the largest effect on CPI is Sweden where the coefficient is at 0.468. Thus indicating that approximately half of the inflation rate can be explained by money supply. The money supply variable is significant at 1% significance level for all countries, meaning that the OLS results show that money supply has a significant impact on CPI. United States money supply is also significant, as well as lagged money supply.

The state space results are presented in the following subsections, 6.1.1-6.1.3.

Table 6.1: OLS regression results, CPI

	Sweden	UK	USA
Money supply	0.468*** (0.078)	0.312*** (0.089)	0.326*** (0.066)
US money supply	0.136* (0.079)	0.159** (0.074)	
Real GDP	-0.635*** (0.109)	-0.186* (0.101)	-0.287*** (0.055)
Exports	0.138*** (0.025)	0.050** (0.020)	0.151*** (0.018)
Money supply, 1 lag	0.277*** (0.073)	0.294*** (0.086)	0.228*** (0.059)
Constant	-0.020*** (0.007)	-0.012** (0.006)	-0.012** (0.004)
<i>N</i>	148	149	152
Adjusted <i>R</i> ²	0.556	0.506	0.552

Note: *, **, and *** denote statistically significant at the 10%, 5%, and 1% significance level, respectively.

The specification for the CPI-state space model can be seen in section 5.2. The graphs can be interpreted as the Money supply coefficients evolution over time, or in general terms: how the relationship between the two variables emerges over time. During time periods of positive values on the Y-axis, the money supply affects inflation positively, and vice versa when the variable takes negative values.

6.1.1 Sweden

Figure 6.1 shows the state space variables evolution over the time period of 1870-2023 within a 95% confidence interval illustrated by the orange lines. SV1 represents the state variable money supply while SV2 represents the state variable money supply with one lag.

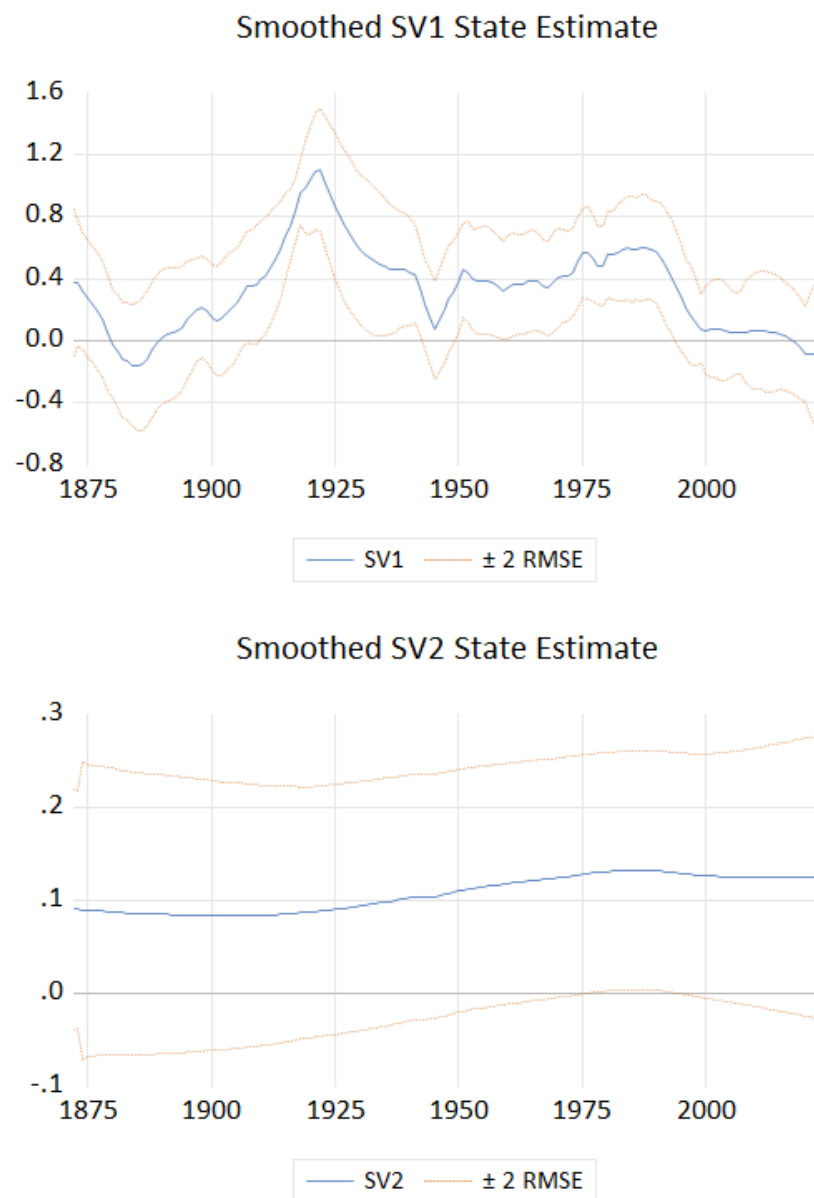


Figure 6.1: Sweden, state space analysis with CPI, 1870-2023

The SV1 graph shows that the relationship seems to have been fairly mean reverting over time, and mostly positive. The mostly positive values mean that increased money supply has increased inflation, i.e. that the two variables are positively correlated. The mean reversion, however, indicates that the link has neither weakened nor strengthened over time. However, we can clearly see a decrease in the link looking at the beginning of the 2000s to levels that have not been seen since the late 1800s. We should note that the weaker link only has been seen during a relatively short period of time, considering the full sample. But it is still worth noting, especially since it is at historically low values.

We will further discuss the reasons behind our empirical analysis based on the monetary and inflationary regimes from a historical perspective.

Figure 6.1 shows that the relationship between money supply and inflation has slowly increased from 1880 up until the peak at the occurrence of the First World War. [Jonung \(2019\)](#) explains that the war was prosperous for Sweden and this caused a rise in inflation. The rise in inflation can clearly be seen in the SV1- graph during this period as the link seems to grow stronger up to where the state variable takes values of almost 1.2 indicating that the relationship between the two variables is even stronger than on-to-one. This confirms the research conducted by [De Grauwe and Polan \(2005\)](#) who finds that the relationship between money supply and inflation grows stronger during periods of high inflation. During the same period, Riksbanken was not an active participant in the monetary policy up until the year 1890. ([Andersson \(2023\)](#), [Lindbeck \(1973\)](#)). Riksbanken was further bound by the Gold Standard at the same time period, 1873-1914. The fact that the link remains strong under the Gold Standard goes against the results by [Rolnick and Weber \(2011\)](#) but may be explained by the extreme inflation environment counteracting the weakened link that is supposed to appear under commodity standards.

After the end of the First World War, the relationship between money supply and inflation once again declined looking at the period 1915-1945. Sweden left the Gold Standard in 1914 and joined the system again in 1924. The declining relationship during non-commodity standards goes further against [Rolnick and Weber \(2011\)](#) however can be explained by [De Fiore et al. \(2022\)](#) that the relationship is weaker during transitions of monetary regimes. It clearly was a period of large economic transitions back and forth between monetary systems.

The link stagnates in 1951 when Sweden entered The Bretton Woods Agreement and ended with a small peak in 1975 around when Sweden left this arrangement. The relationship gradually increases in Sweden after a peak in relation to leaving Bretton Woods. From 1950 to 1975 the full employment policy was still intact making it difficult to navigate in the high inflation periods of the 1970s as followed by the OPEC crisis, this can be seen as a slight increase in the link in figure 6.4 for the SV1 state variable as in line with [Borio et al. \(2023\)](#) and [De Grauwe and Polan \(2005\)](#) that high inflation environments make the link stronger.

We see a steep decline in the link from the year 1980 and onwards, the link is even negative during the late 2020s. This is in line with [Sargent and Surico \(2011\)](#) and [Papadia and Cadamuro \(2021\)](#) who conclude that a reason for the link to weakened in modern times is due to new monetary rules effectively counteracting inflationary pressure. The 1980s was further a time of financial innovation and economic liberalization which revolutionized the Swedish credit market through November-revolutionen. An explanation for the weakening link could therefore also be the

financial liberalization in line with [De Grauwe and Polan \(2005\)](#). The decreasing effect of money supply on inflation in the mid/late-1990s coincided with the new monetary policy of the Swedish Central Bank as a consequence of the economic crisis that followed the housing bubble in the early 1990s.

Except for the peak in the early 1920s and the subsequent decline in the money supply effect on inflation, the relationship has remained mostly stable and positive.

Low and stable inflation in Sweden since the 2000s combined with monetary expansion confirms our empirical findings, the link between money supply and inflation appears to be weak, non-existent, and even negative in the most recent years to date. These findings stand in contrast to the quantity theory of money thus confirming the research finding that the evidence for the quantity theory of money is non-existent over the last 30 years by for example [Estrella and Mishkin \(1997\)](#) and [Sargent and Surico \(2011\)](#).

Further the lagged money supply, state variable SV2, shows slightly increasing specifically during 1925-1980. Thus indicating that the lagged money supply's effect on inflation is insensitive to previous time periods. However, it is worth noting that the state value remain above 0.1 even when the unlagged state variable is ≤ 0 during the 2000s indicating that there exist a lagged positive effect of the money supply on inflation, and that is stable, even during time periods when the unlagged link is non-existent.

The recent slight decline in state variable SV2 departs from the the decline in the 2020s mainly because of the contradicting money supply, CPI, and Real GDP implies lacking relationships between those, this decline in relationship might be due to something different than previous research has concluded.

6.1.2 The United Kingdom

Figure 6.2 shows the state variables evolution over time for the UK. Considering the confidence interval, it is more narrow as compared to Sweden indicating potentially less reliable results. The top graph shows the state variable, SV1, depicting the link between money supply and inflation. The lower graph shows the state variable, SV2, depicting the link between lagged money supply and inflation. Considering SV1, the relationship overall seem to be more sensitive to shocks as compared to Sweden (figure 6.1). This potentially due to the UK being a larger economy less dependent on exogenous variables originating from the world economy. As it is more volatile, we also get higher values on the Y-axis in order for the state space model to capture the average of the OLS estimate over time. The high volatility means that it may be hard to draw specific conclusions on what happened during the specific peaks, but one can draw some general conclusions. The lagged money supply graph (SV2) does not show any sign of a time-varying relationship. However, it shows a positive relationship which seem to be stable over time. This means a constant positive link between lagged money supply and inflation over time. We will thus focus the further analysis on the non-lagged graph, with state variable SV1.

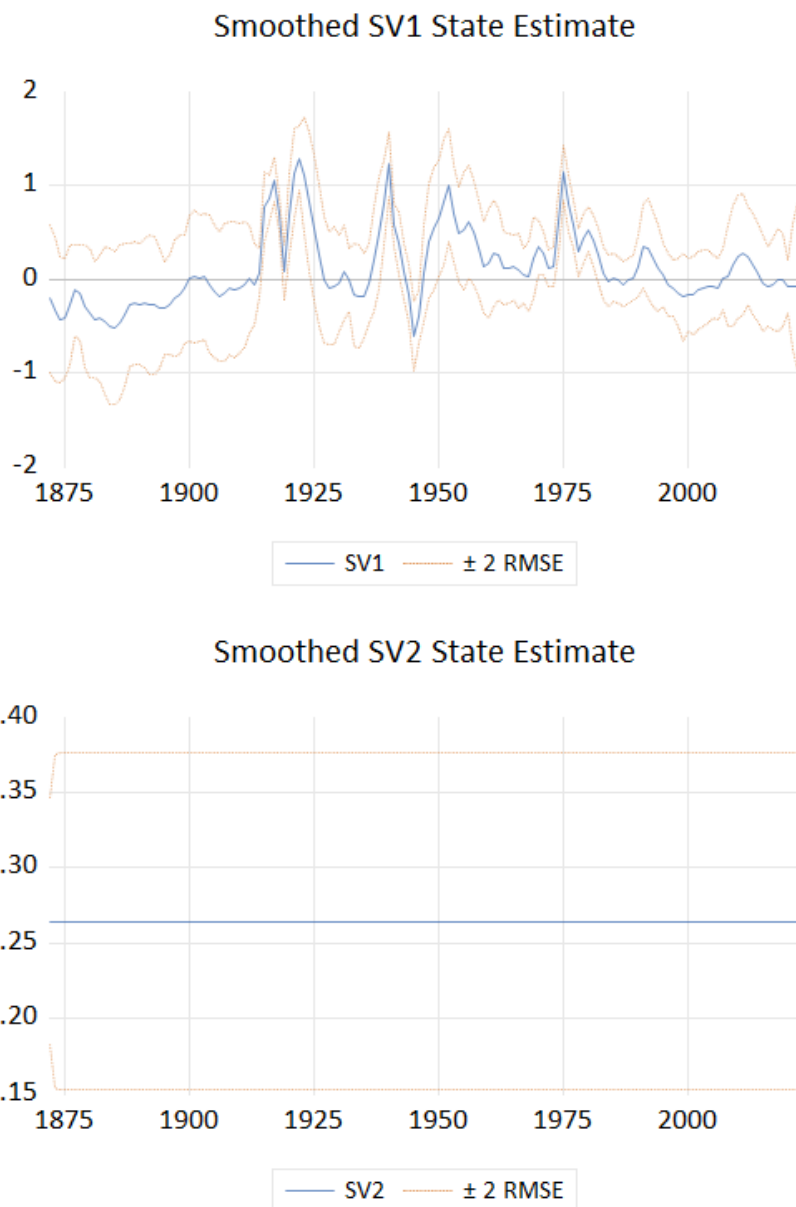


Figure 6.2: United kingdom, state space analysis 1870-2023 with CPI

During the early years, 1875-1910, the relationship is negative and close to 0. This was a period when the Bank of England did not have any power over the money supply, the currency was pegged against gold and the exchange rate was changed frequently. The fact that the relationship was negative during this period, i.e. that money supply decreased inflation, is interesting. One could argue that it is in line with [De Fiore et al. \(2022\)](#) that the link is weak or non-existent during regime changes if we view an uncertain time as regime change. One could further argue that it confirms [Rolnick and Weber \(2011\)](#) that the link is weaker under commodity standards. However, these researchers do not conclude anything about the link being negative.

The Bank of England abandoned the gold standard after experiencing high inflation in year 1914. The inflation and the abandoning of the gold standard may be

the causes behind the peaks in the relationship between money supply and inflation looking at the graph years 1910-1930. This is in line with the research conducted by [De Grauwe and Polan \(2005\)](#) and [Borio et al. \(2023\)](#) that higher inflation results in a stronger link, as well as with [Rolnick and Weber \(2011\)](#) that the link is stronger under fiat systems. It further could confirm the results by [Christiano and Fitzgerald \(2003\)](#) and [Dwyer Jr. and Hafer \(1988\)](#) regarding the long-run link. In the period prior to the peak, the Bank of England took control over the money supply meaning a more active increase in the money supply. The peaks could be a lagged effect of this increase in money supply.

Furthermore, there was an extensive change in monetary regimes during the later period. The United Kingdom both joined and left the Bretton Woods system in the 1950s. That combined with the war-loan agreement and post-war consequences indicates this was a turbulent economic time for the UK with several monetary regime changes, thus providing us with some explanation for the high volatility in the link between money supply and inflation.

Similar to Sweden, the link seems to have gradually weakened and even turned negative looking at the graph from the year 1975. This is in line with the results from [Estrella and Mishkin \(1997\)](#) who conclude that the link between money supply and inflation has lost relevance in recent years. However, as the 1980s was characterized by financial liberalization in the US this could have a spillover effect on the UK. It is reasonable to assume that a growing part of the UK money stock has gone towards financial investments in the US meaning a lesser part has gone into the UK real economy. Thus confirming [Gertler and Hoffmann \(2018\)](#). Furthermore, this is also a period when the Bank of England implemented inflation targeting indicating that inflationary pressure more effectively was counteracted thus weakening the link, this in line with [Sargent and Surico \(2011\)](#) and [Papadia and Cadamuro \(2021\)](#).

6.1.3 The United States

Figure 6.3 shows the state space variables evolution over time for the United States. The graphs differ as compared to Sweden and the United Kingdom. The lagged money supply (SV2) seems to be more sensitive, while the unlagged money supply (SV1) is less sensitive over time. The state variable SV2 in Figure 6.2 indicates that the lagged effect on inflation in the United Kingdom is completely time invariant while the United States SV2 state variable in Figure 6.3 shows highly time-varying patterns. The unlagged money supply in the United States has stabilized the inflationary effect of monetary expansions at around 0.2 with a slight decline in recent years. Compared to Sweden and the United Kingdom, this relationship between money supply and inflation in the United States is not as sensitive to exogenous changes and holds more stable characteristics for long time periods. The interesting result here, however, is the lagged SV2 graph. We will thus focus on this in the further discussion.

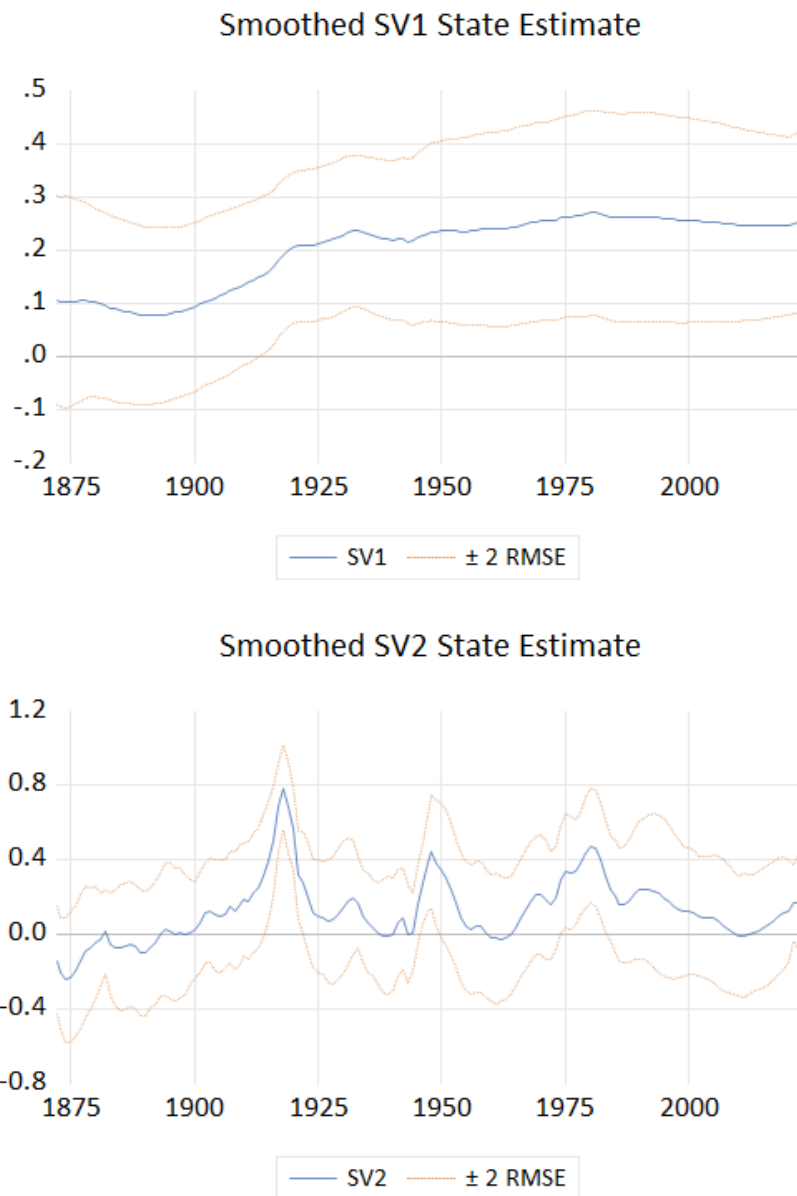


Figure 6.3: United States, state space analysis 1870-2023 with CPI

In figure 6.3 we see an increase in the state variable i.e. an increase in the link between CPI and money supply from the year 1875 to the late 1910s. This holds for both the lagged (SV2) and the unlagged (SV1) state variable but with a steeper trend in the lagged figure and a longer period of increase in the SV1. After this period, during the mid-1910s, the Federal Reserve was implemented. However, during about the same period in 1915-1920, there was a surge in the inflation rate. We see an increasing link at around the 1910s and a decreasing link a few years before 1925. The high inflation rate could be seen as the reasons behind the strengthening of the link. Thus confirming [Borio et al. \(2023\)](#) and [De Grauwe and Polan \(2005\)](#). However, as we see a weakening link quickly after the inflation surge it is hard to draw certain conclusions.

In 1925, the United States implemented the Gold Exchange Standard and inflation stabilized. This could be seen in the graph as the state variable SV2 becoming

more stable and weaker over the years 1925-1940. We see the same stable relationship in the SV1 graph. This further confirms [Sargent and Surico \(2011\)](#).

There is no direct effect of the deflation during the Great Depression 1929-1939, which implies that the increased relation between money and inflation in extreme inflation regimes according to [De Grauwe and Polan \(2005\)](#) and [Borio et al. \(2023\)](#) only is applicable in positive extreme inflation regimes.

During the Second World War, 1939-1945, money supply and inflation increased. We can clearly see this in the SV2 graph, the state variable clearly increased during this period. The price regulations kept the link between money supply and inflation weak at first, however inevitably increased the link up until its peak right before the 1950s.

The Bretton Woods systems collapse in 1971 is further observable in the graph. The state variable increases again to its peak at around 1980 returning to approximately the same level as the latest peak at 1950. Thus in line with [Sargent and Surico \(2011\)](#), the link is strengthened under non-commodity standards. On top of the collapse of the Bretton Woods, the oil crisis in the 1970s shocked the markets inducing more uncertainty. Thus confirming [De Fiore et al. \(2022\)](#) that under changing economic conditions inflation is hard to predict and counteract, thus weakening the link between inflation and macroeconomic variables such as money supply.

The state variable decreases from the 1980s over 30 years until the beginning of 2010. This confirms the empirical literature results (see for example [Estrella and Mishkin \(1997\)](#), [Christiano and Fitzgerald \(2003\)](#)) that the quantity theory of money no longer seems to be related in recent years. However, we can clearly see in the unlagged graph as well as in the time period overall that it still matters. The link seems to depend on underlying economic conditions. Further, higher inflation and a larger amount of economic instability make the relation between the two variables stronger. This further confirms the results by for example [De Grauwe and Polan \(2005\)](#) and [De Fiore et al. \(2022\)](#) that the link between money supply and inflation depends on the underlying inflation regime.

We can further look at the specific result regarding the links weakening during the period of financial deregulation, financial innovations and globalization in the light of [Gertler and Hoffmann \(2018\)](#) who argue that institutions have started using money in a way that does not show up in the real economy, and thus not as CPI inflation. This could be a potential explanation and we will analyze this further in the next section where we present the results on the link between money supply and housing prices.

6.2 Housing price-model

There is a clear tendency for the link between inflation and money supply to have weakened since the 1980s, which can be seen in figures 6.1-6.3. Under this section, we analyze a potential explanation for this weakening link: an increased link between asset prices and inflation due to financial deregulation. Here, the system of equations 5.7,5.8 and the other system 5.9,5.10 are being used.

Table 6.2 shows the OLS output for the model using the housing price index as the dependent variable.

Table 6.2: OLS regression results, housing price index

	Sweden	UK	USA
Money supply	0.252* (0.132)	0.629*** (0.150)	0.741*** (0.150)
US money supply	0.214 (0.148)	0.006 (0.004)	
Real GDP	0.137 (0.181)	0.084** (0.286)	-0.523*** (0.130)
Long term interest rate	0.005 (0.024)	0.116 (0.072)	0.090 (0.044)*
Constant	0.005 (0.012)	-0.027* (0.015)	0.006 (0.010)
N	144	107	130
Adjusted R^2	0.072	0.287	0.167

Note: *, **, and *** denote statistically significant at the 10%, 5%, and 1% significance level, respectively.

In this model, money supply seems to have the largest effect on US housing prices with a coefficient of 0.741. We see that the money supply variable is significant at a 1% level for the United States and the United Kingdom. For Sweden, the money supply variable is only significant at a 10% level. Potentially indicating that the state space output with housing prices for Sweden is less reliable as compared to using CPI as dependent variable where money supply was significant at 1% for all countries. But, as mentioned before, we are mainly interested in seeing how the relation moves over time which we will still be able to do by looking at the output from the state space model. The state space results are presented in the following subsections, 6.2.1-6.2.3

6.2.1 Sweden

Figure 6.4 shows the state variable housing price index and its relation to money supply over time. The timespan is more narrow as compared to the model on CPI and money, the timespan here is from 1875-2020.

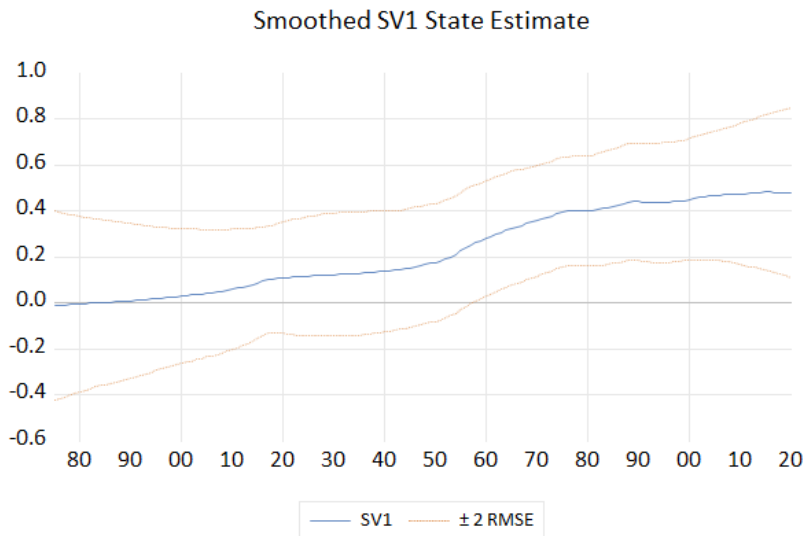


Figure 6.4: Sweden, state space analysis 1875-2020 with housing price index

In Figure 6.4 we clearly see that the effect of money supply on housing prices has increased over the entire time period. From the 1950s until the 1980s, the rate of increase accelerated. During the later years, the link has remained more stable but at positive and historically high levels. One can conclude that since the Bretton Woods Agreement the relationship between money supply and asset prices has become more significant and that this relation peaks and stabilizes when Sweden deregulates the credit market and transforms the main objective of the Riksbanken to price stabilization targets. It is interesting to note that the relationship between inflation and CPI in figure 6.1 for the last 20 years is close to 0 for the last 20 years and at historically low levels. At the same time, figure 6.4 above shows that the relationship between the housing price index and money supply has remained positive and at historically high levels. This would imply that when increasing the money supply the flow of money went into the housing market and assets, and not into the general economy. There are clear signs that the increased money supply has been stored in the housing market, increasing the prices while showing no effect on CPI inflation. This sheds light on the research by [Cechetti et al. \(2002\)](#) that asset prices should not be overlooked in monetary policy decision-making and [Schwartz \(2003\)](#) that asset prices could be affected by growth in the money stock. One might assume that the market liberalization and the introduction of a price stabilization policy target, using CPI as inflation measure, caused this shift in the relationship. Thus indicating that the inflation target is flawed. However, the increase of the link between housing prices and money supply has increased over the entire time period starting with a steeper increase during the 1950s. The inflation target and the financial liberalisation can therefore not entirely be held accountable for the increase.

6.2.2 The United Kingdom

Figure 6.5 shows the state variable housing prices and depicts the link between housing prices and money supply over the period 1899-2020.

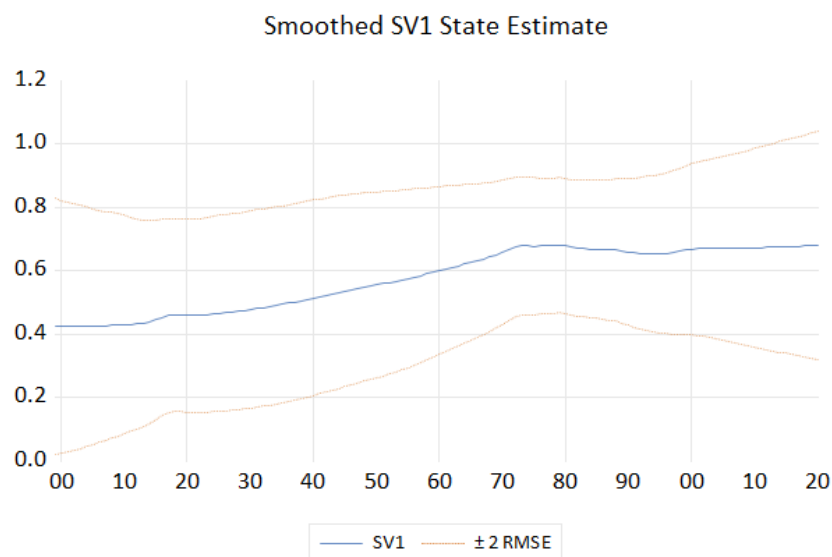


Figure 6.5: United Kingdom, state space analysis 1899-2020 with housing price index

In general, the United Kingdom shows a similar trend as Sweden, but with an earlier peak in the steepness during the 1970s. In Sweden, we saw the peak in steepness around the 1980s. The money supply effect on asset prices had a stable upward positive trend up until the 1970s when the link stagnated at a stable and positive level of 0.7. Considering the evolution of the state variable of CPI in Figure 6.2, the period of decreased volatility starting in 1975 could be an explanation for the stagnation of the housing prices state variable in the 1980s. Thus indicating that during periods of uncertainty, there is a volatile link between CPI and money supply, and an increasing link between housing prices and money supply. Potentially due to uncertainty meaning households, firms, and institutions want to have safer assets in their portfolio such as property. However, as the increase stagnates and has remained stable during the last 50 years, we can not confirm the hypothesis by [Borio et al. \(2023\)](#) that a weakening link between CPI and money supply instead manifests as a stronger link between assets and money supply using housing prices as the asset variable. It could be, however, that the strengthening link shows up in different assets and when weighing different asset classes together, as the housing market obviously is very much affected by other variables as well. The movements are slower than Sweden's, implying they may be more affected by external shocks not incorporated into this model.

6.2.3 The United States

Figure 6.6 shows the link between asset prices and money supply from 1890-2020.

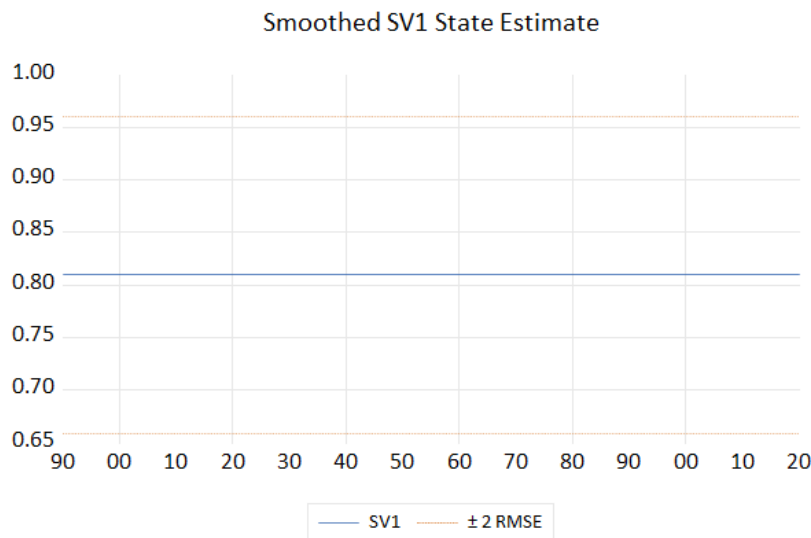


Figure 6.6: United States, state space analysis 1890-2020 with housing price index

Surprisingly, the graph in Figure 6.6 provides no empirical evidence for the money supply to have a time-varying effect on housing prices. However, the relationship remains positive at 0.8 over time. The reasoning behind this could simply be that the US more effectively can affect the link between money supply and inflation as they are not as affected by other countries' monetary decisions. Thus making the link time-invariant.

7

Conclusion

This research paper analyzes the relationship between money supply and inflation as well as the relationship between money supply and a housing price index. The scope of this paper narrows down to Sweden, the United Kingdom, and the United States during the time period of 1870-2023. This comparative analysis is conducted with a state space model to evaluate the relationship under different economic landmarks and changing monetary regimes.

We find a time-varying relationship between money supply and inflation in Sweden, the United Kingdom, and the United States. For the United States, the effect is mainly present looking at money supply as a lagged variable whereas for the other countries, the effect is mainly present looking at unlagged money supply.

There is a clear tendency for all countries that the link has been weak and close to 0 over the past 50 years, thus confirming previous research.

We see signs of the underlying inflationary and monetary regime affecting the link. Thus implying that the link between money supply and price level should not be dismissed just on the basis that the link has been weak in recent years. Clearly, the inflationary and monetary regimes have been such that the link has been weak since the 1980s. However, inflationary and monetary regimes can quickly change and with that, the link between inflation and money supply will change. We can further conclude that it is important to look at the long run. The economy is complex and only studying for a few years can clearly give the wrong impression of how this relationship works.

Further, the results suggest that the relationship between money and inflation tends to increase in times of extreme inflation regimes. However, this result does not manifest in increased relationships in times of deflation.

We also find a positive relationship between housing prices and money supply for all countries. The link between housing prices and money supply is not as time-varying as the link between CPI and money, but it shows an upward trend for the United Kingdom and Sweden. For the United States, the link is stable and positive.

We find an interesting result that simultaneously as the link between CPI and money supply is at historically weak levels, the link between money supply and housing prices is at historically strong levels. We can thus suspect that a decrease in the link between money supply and CPI manifests in a stronger link between asset prices and money supply. Indicating that when the money supply increases and it has no effect on CPI, it may have an effect on other prices such as housing prices. Potentially due to more money being put towards the financial sector thus not

manifesting in consumer prices and the real economy but rather in financial assets not showing up in the CPI. It is clear that the financial deregulations and inflation targets may be a reason for this, and that central banks may need to adjust their measurements of inflation. It is also worth noting the tendency for decision-makers to act on immediate problems, losing the long-run perspective. From the historical background one can conclude that monetary solutions often create a window for monetary problems. Thus one should be vigilant towards the presumably stable new monetary order that consists mainly of inflation targeting.

There exist lags in all macroeconomic variables, and it is therefore not possible to conclude causal relationships just by analyzing the state space graphs. It is further clear that events that theoretically would result in a certain strengthening or weakening of the link can happen simultaneously. Thus making it hard to determine the reasons for some shifts in the link. Further, the housing price model is less robust. Partly due to the more narrow time interval, and partly due there existing many variables affecting the housing market.

Housing prices are clearly not the same as asset prices and research should therefore be conducted on the relationship between asset prices and money supply, investigating more asset classes and indexes over assets. Furthermore, research should be conducted on why it is that the link is weak during certain inflationary and monetary regimes.

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Appendix A

State space estimates

Table A.1: SSP output, consumer prices

Country	Variable	Coefficient (Standard Error)
Sweden	Real GDP	-0.520*** (0.083)
	US money supply	0.156** (0.074)
	Exports	0.119*** (0.011)
Final state		
	Money Supply	-0.088 (0.285)
	Money supply(-1)	0.124 (0.075)
UK	Real GDP	-0.111** (0.048)
	US money supply	0.096 (0.060)
	Exports	0.074*** (0.012)
Final state		
	Money supply	-0.08 (0.628)
	Money supply(-1)	0.265*** (0.056)
USA	Real GDP	-0.160*** (0.050)
	Exports	0.131*** (0.011)
Final state		
	Money supply	0.251*** (0.090)
	Money supply(-1)	0.180 (0.170)

Table A.2: SSP output, housing price index

Country	Variable	Coefficient (Standard Error)
Sweden	Real GDP	0.281* (0.165)
	Long term interest rate	0.011 (0.053)
	Money Supply US	0.281* (0.165)
Final state		
	Money supply	0.479** (0.188)
UK	Real GDP	0.585** (0.247)
	Long term interest rate	0.094 (0.106)
	US money supply	0.001 (0.005)
Final state		
	Money supply	0.678*** (0.183)
USA	Real GDP	-0.528*** (0.126)
	Long term interest rate	0.090 (0.077)
Final state		
	Money supply	0.810*** (0.076)