Determinants of Inflation

Evidence from Sweden

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Abstract

This thesis examines what have been the main drivers of inflation in Sweden in recent years. This is done through the New Keynesian Phillips Curve with marginal cost which serves as the theoretical background to explain inflationary behavior. An extension to the New Keynesian Phillips Curve with marginal cost is made by adding four suggested inflation drivers apparent in recent years. The contributions of each driver to inflation development are estimated using a Structural Vector Autoregression model with Bayesian methods. The result showed that inflation in 2020 was mainly driven by the output gap and labor market activity, whilst in 2021 more transitory shocks such as energy price and supply chain shocks were more prevalent. The forecast from the model indicates that energy prices and foreign monetary policy shocks will be more dominating. A shift can be seen as Sweden hit the Zero Lower Bound with monetary policy importance almost disappearing, government spending became partly deflationary and stronger influence from energy prices. Robustness tests support the results with, e.g. a more parsimonious model, albeit with more contribution from government spending. Lastly, the results support that the relationship of the New Keynesian Phillips Curve still holds to a degree, although when considering other periods, other extensions may be preferred.

Keywords: Bayesian Vector Autoregression, Structural Vector Autoregression, New Keynesian Phillips Curve, Inflation, Sign and Zero Restrictions

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List of Abbreviations

BSVAR Bayesian Structural Vector Autoregression

CPIF Consumer Price Index with Fixed Rates

E*/P Employment to Population Ratio

ECB European Central Bank

EURIBOR Euro Interbank Offered Rate

FED Federal Reserve

FEVD Forecast Error Variance Decomposition

FRED Federal Reserve Economic Data

GSCPI Global Supply Chain Pressure Index

HD Historical Decomposition

IRF Impulse Response Function

KIX Krona Index

NKPC New Keynesian Phillips Curve

PC Phillips Curve

SEK Swedish krona

SOE Small Open Economy

SVAR Structural Vector Autoregression

SZR Sign- and Zero-restrictions

VAR Vector Autoregression

ZLB Zero Lower Bound

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1 Introduction

Sweden has experienced a long period of significantly low inflation rates, with a mean annual rate of 1.7 % from 1992 to 2021. However, as this thesis is being written, the highest measured inflation rate for 30 years was announced by the Swedish Riksbank at 6.4 % in April 2022. The Swedish Riksbank responded to this on 5 May 2022 by raising the policy rate, which had for a long time remained at zero and below, to 0.25, making it positive for the first time since 2014. The recent development of inflation has sparked debate amongst scholars, economists, and policymakers as they are trying to figure out the leading causes of the drastic change and how it should best be dealt with.

The question this thesis sets out to answer is the following:

What are the main drivers of inflation in recent years in Sweden, and to what degree have they each contributed to movements in the inflation rate?

Inflation has puzzled economists far back in history. As economic systems have developed and advanced, new theories and models have emerged, and old ones have been reevaluated. For example, researchers have tried to model inflation through quantitative measures, i.e. as the equation of exchange, and through the inverse relationship between inflation and unemployment, i.e. the Phillips curve (PC). While today most economists use Dynamic Stochastic General Equilibrium (DSGE) models with advanced computations of relationships between thousands of different variables.

With inflation rising again and world events and development deviating from the status quo, it is essential to acknowledge this new environment and evaluate the situation accordingly. However, former relationships may not hold as under usual circumstances, and it is essential not to make decisions as if nothing has changed. Therefore, this thesis examines how inflationary factors and relationships can vary over time and which ones have been most prominent in recent years.

The question of what have been the main drivers of inflation, both recently and historically, is answered using a structural Vector Autoregression (SVAR) model with Bayesian methods (BSVAR) that gives us information on how much movements in inflation are due to the suggested channels. The main estimation includes inflation, four suggested channels (Employment-to-population gap (E*/P), government spending, supply chain and energy prices) and four standard macroeconomic variables (The output gap, foreign and domestic policy rates and the exchange rate). Furthermore, robustness tests are conducted with a more parsimonious model as well with a split sample when the Zero Lower Bound (ZLB)

The results show that the output gap and a drop in labour market activity were the most significant drivers of inflation during 2020. However, the driving forces in 2021 are more divided, although the output gap and labour market activity are still significant contributors. In addition, supply chain disruptions drove up inflation throughout 2020 and 2021, whereas energy prices contributed to both upwards and downwards inflationary pressure. Moreover, government spending had a more pronounced effect when omitting policy rates. Lastly, a binding ZLB changed inflation's response to different shocks, most noticeably the response to government spending and energy price shocks.

This thesis contributes to the literature in four ways. Firstly, it is a novelty as it is unique by analysing all the suggested drivers and their simultaneous effect on inflation. Secondly, it outlines the recent inflationary environment and its drivers in Sweden and how this scenario connects to the New Keynesian Phillips Curve (NKPC). Thirdly, it provides an example of applying a BSVAR model to analyse inflationary dynamics. Fourth, it contributes to a further nuanced understanding of inflation, especially during times of crisis and rare events.

The remainder of the thesis is structured in the following manner. Section 2 explains and motivates the theoretical outline of the NKPC and provides an overview of previous studies that have been done related to this subject. Next, Section 3 presents background information concerning the recent inflationary environment in Sweden, including the suggested drivers and a proposed revision of the NKPC. After that comes Section 4 with a description and an evaluation of the data used in this thesis. Section 5 states the empirical methodology of the BSVAR, what empirical tools are to be used and how the application of the model. Section 6 presents the results of the main estimations and model with accompanying discussion and of policy actions being taken by Swedish authorities. Section 7 contains robustness tests to strengthen the reliability of the model. Finally, in section 8, the thesis is briefly summarized and concluded.

2 Literature Review and Theoretical Background

This section highlights what others have done within the roam of inflation dynamics and gives a detailed description of the NKPC.

2.1 Previous Research on Determinants of Inflation

Earlier studies that have analysed inflationary dynamics have often used SVAR models. For example, Caldara & Kamps (2008) analysed the effects of a business cycle shock, a government spending shock and a tax shock on several macroeconomic variables, one of which was inflation, using a SVAR. Moreover, they tested the shocks using four different identification approaches, a recursive, a non-recursive, a sign-restriction and an event study approach. They concluded that all identification approaches yielded similar results for the government spending shock but not for the tax shock.

Jovičić & Kunovac (2017) studied what drives inflation and GDP (Gross Domestic Product) in a small open European economy, specifically, Croatia. They made use of a SVAR, Sign and Zero-Restrictions (SZR) and block-exogeneity. Moreover, they estimated their SVAR using Bayesian methods and included global, European and domestic shocks. They concluded that global factors had the most prominent effects on the drop in Croatian inflation. Furthermore, they concluded that European monetary policy and oil price shocks had a modest effect on both GDP and inflation.

Moving on to Sweden specifically, Corbo & Di Casola (2022) studied what contributed to fluctuations in consumer prices and the exchange rate in the Swedish economy, using a BSVAR and SZRs. Moreover, they used historical decomposition (HD) and forecast error variance decomposition (FEVD) as econometric tools to analyse inflation and exchange rate dynamics. They concluded that the main driver of consumer prices in Sweden was a global demand shock.

A lot of the literature examining inflationary dynamics focuses on examining the NKPC. The research mainly concerns what types of proxies should be included and how strong the suggested relationships are. Malikane & Mokoka (2014) conducted an alternative approach to studying the NKPC. In addition to estimating the coefficients of its components, they also compute partial correlation coefficients and Marginal R-squared. This is done to see to what degree the disaggregated components in the NKPC contribute to inflation. They conclude that supply shock variables dominate in contribution to inflation whilst other more conventional components (output gap and labour share) had less importance. They recommend further tests of the NKPC to reexamine the importance of including the output gap and the labour share and if other parts should be added.

Much research has also been done to examine inflationary dynamics when the ZLB is binding. For example, Choi, Shin, & Yoo (2022) analysed changes in the behaviour of inflation from a government spending shock with a binding ZLB. They found that inflation did react differently when the ZLB was binding. In fact, contrary to standard New Keynesian theory, government spending became disinflationary. Moreover, Datta, Johannsen, Kwon & Vigfusson (2021) studied the dynamics between oil prices and equity returns with and without a binding ZLB. They found that correlation did increase with a binding ZLB. Furthermore, they concluded that oil prices became more responsive to macroeconomic shifts than before ZLB.

Moving on to research conducted to analyse the absolute recent inflation development. Celasun, Hansen, Mineshima, Spector & Zhou (2022) conducted a SVAR analysis to examine whether supply chain bottlenecks were more driven by the demand or supply-side factors. The results show that the demand-side factors have dominated, even though supply-side factors have had a noticeable contribution, especially in countries where pandemic restrictions still are evident. Bhushan & Struyven (2021) conducted a similar study examining how demand and supply-side factors contributed to longer delivery times and found that the surge was mainly demand-driven. As a result, they forecasted that inflation would initially increase in the US and the EU but return to standard rates at the end of 2022. However, actual inflation rates have more than doubled compared to what they forecasted.

Christoffel, Costain, De Walque, Kuester, Linzert, Millard & Pierrard (2009) evaluate the influences of labour markets on inflation under different new Keynesian model specifications. Specification with sticky wages and right-to-manage bargaining, i.e. that wage contracts are agreed to first before firms choose the working hours that maximize their profits, was best to model reality. However, the results depended much on the microeconomic structure of the model, so they emphasised that further research should examine the most realistic way to set up the labour market to explain its effects on inflation better.

We further contribute to the existing literature by assessing the inflationary dynamics in Sweden during the uncertain economic environment seen in recent years. Moreover, we further evaluate the existence of the NKPC in a small open economy (SOE) and are the first study to examine the relationship of these new four drivers simultaneously.

2.2 The New Keynesian Phillips Curve

The relationship most frequently examined in low inflation environments is between real activity (mobility in the labour market) and business cycles, which economists often explain by using the PC. The classical PC was named in the 1960s by Samuelson & Solow (1960) after the semantic work of Phillips (1958), who had examined the negative relationship between unemployment and inflation. The PC became one of the most fundamental macroeconomic and monetary policymaking concepts. The PC is a single-equation that states that as unemployment decreases in an economy, wages are driven up, which in turn causes inflationary pressure and higher price levels. This relationship was briefly dissolved due to stagflation in the 1970s as several economies experienced high unemployment and high inflation periods.

In the context of Sweden, Karlsson & Österholm (2020) estimated the PC using a Bayesian VAR model with time-varying parameters over the period 1995-2018. They found the PC to be unstable and, in contrast to those suggesting the PC to flatten, it is not the flattening of the PC that has caused low inflation rates in Sweden in recent years. Andersson & Jonung (2020) replied to their paper, questioning their lack of incorporating international aspects when examining the PC. They suggested that since Sweden is deeply integrated with the European economy, there is no longer a pure Swedish PC but an international one. It is argued that Swedish inflation is more correlated with the European business cycles than its own.

The primary liability of the PC was that it was too simplistic and failed to describe the economic behaviours of reality adequately. However, the PC is still in use but with modifications. Friedman (1968) and Phelps (1968) argued that the PC does not hold in the long run as monetary policy can not affect unemployment due to there being a “natural unemployment rate” that the economy always moves back to. They did, however, argue that there exist deviations from this long-run level, allowing a short-run PC (also called “the expectations-augmented PC” as the curve may shift if expectations of future inflation alter) to exist. This is in line with the viewpoint of New Keynesian economics that households and firms have rational expectations. The NKPC stems from the assumption of "sticky" prices in the economy due to imperfect competition in wage and price setting, causing sluggish adjustment to changed economic conditions. The NKPC builds on the theories of staggering contracts from Taylor (1980) and Calvo (1983) and the quadratic price adjustment cost model of Rotemberg (1982).

Roberts (1995), who was the first to derive the NKPC, initially included expected inflation and the output gap to reflect real economic activity. The output gap is the difference between actual and potential output. If the output gap is positive, the economy exceeds its potential output, which causes inflationary pressure. However, researchers realized that the output gap was not suitable to be the main driving force of inflation and replaced it with the real marginal cost (e.g. Galı & Gertler (1999); Sbordone (2002); Woodford (2001)). The reasoning behind this was that because firms base their prices on marginal costs, then, if marginal costs rise, firms would have to raise their prices accordingly to keep their profit margins, creating inflationary pressures. Therefore, the marginal cost-based NKPC would better reflect the relationship between inflation and economic activity as real marginal cost better incorporated changes in productivity. This assumption has also been confirmed by empirical research.

The New Keynesian framework state that some firms are forward-looking and quickly and often alter their prices while others are backwards-looking and seldom do it. This creates price stickiness and thereby inflation persistence, often represented in the NKPC as a lagged value for inflation. Fuhrer & Moore (1995) proves that including a lag of inflation in the NKPC improves the fit compared to the purely forward-looking one. This leads to the hybrid NKPC model following Galı & Gertler (1999) and Galí, Gertler, & Lopez-Salido (2001) in (1).

$$\pi_t = \alpha_f E_t \pi_{t+1} + \alpha_b \pi_{t-1} + \lambda \widehat{mc_t} \tag{1}$$

Due to Sweden being a SOE that is vulnerable to uncertainties and shocks abroad Stockhammar & Österholm (2016, 2017), one needs to account for the effects trade openness and exchange rate dynamics have on inflation in Sweden. Batini, Jackson, & Nickell (2005) realized this and extended the model of Galı & Gertler (1999) to go from representing a closed economy to an open one by incorporating the effect international trade has on inflation. They did this by including employment adjustment costs, relative prices of imported inputs and foreign competition pressures, thereby increasing the fit of the NKPC. This is acknowledged in (2) by including a weighted term that includes the difference between the prices of imports and domestic prices following Gali & Monacelli (2005) the open hybrid NKPC.

$$\pi_t = \alpha_f E_t \pi_{t+1} + \alpha_b \pi_{t-1} + \lambda[(1-\alpha)mc_t + \alpha(p_t^m - p_t)] \quad (2)$$

Rudd & Whelan (2005, 2006) criticise the use of including a forward-looking component as it produces upward biases. It is argued that including inflation expectations makes the curve fail to consider all the earlier expectations incorporated through the dependence on inflation's lags. Further discussions concerning the NKPC have centred around the suggestion of it to be flattening. Kuester, Müller, & Stölting (2009) estimated the NKPC and argued that it is flat, which contradicts microeconomic evidence of frequently occurring price adjustments. The authors explain this to be due to the NKPC not fully capturing the effects of cost-push shocks.

As described in Section 3.3, unforeseen and extraordinary developments have occurred in recent years. Simultaneously, we have been moving from persistently low inflation rates to historically high ones. Because of this, this thesis argues that the conventional NKPC cannot capture the inflationary dynamics currently affecting Sweden and that it requiers a revision, as proposed in Section 3.3.

3 Modern Inflation Dynamics

3.1 Inflation in Sweden

This section describes how inflation and monetary policy have been developing in Sweden in modern times. As seen in Figure 1, Sweden has for the last 30 years experienced stable inflation rates which have stayed close to the target of 2%. Sweden had not experienced anything like the recent surge in inflation ever since the beginning of the 1990's when Sweden was in an economic crisis (Sveriges Riksbank, 2018). In Figure 2, the development of the Swedish primary policy rate is displayed. It can be seen that it has steadily decreased ever since the crisis in the 1990s, with the exception of the Great Recession. The rate turned negative between 2015 to 2020 and became positive again for the first time since 2014 in May 2022. The recent increase in the policy rate responded to recent economic developments.

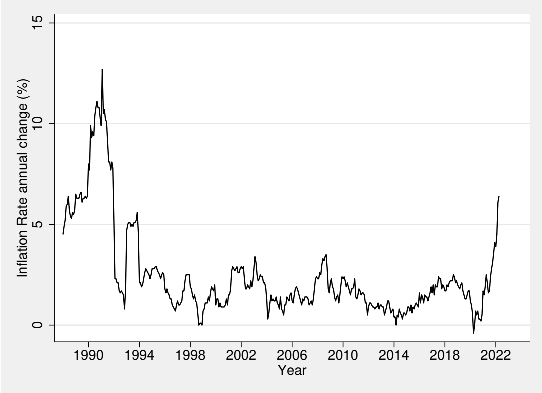

Figure 1: Inflation rate, annual change (%)

Source: Statistics Sweden

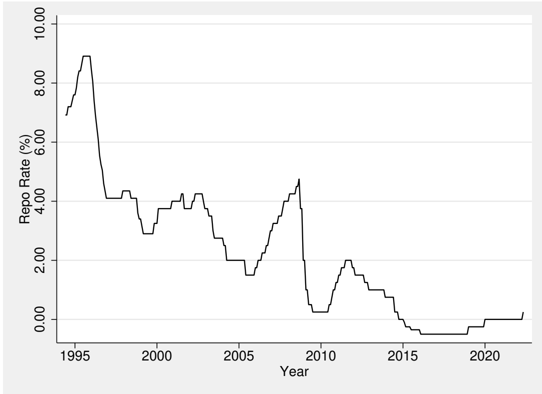

Figure 2: Repo Rate (%)

Source: Riksbanken

The successive decrease led the Riksbank to enter a liquidity trap and face the ZLB, meaning that conventional monetary policy use of policy rate turned ineffective. This led to the Riksbank turning to unconventional monetary policies to avoid deflation. One of these was quantitative easing, i.e. when the Riksbank buys governmental- and corporate bonds to promote investment and stimulate the economy. As a result, the asset purchases of the Sveriges Riksbank (2022b) increased rapidly as their total value of holdings of securities more than doubled from 400 billion in 2020 to 900 billion SEK at the beginning of 2022. However, the purchase rate has slowed down since the beginning of the pandemic and they have announced that the purchases of treasury bills would end in April 2022.

Sustained high inflation rate can be costly for many agents in the economy. Firstly, sustained higher rates causes the purchasing power of house holds to decrease, lowering demand and hampering economic activity. Costs related managing the high changes in prices can also hamper economic activity. Secondly, high rates implies higher uncertainty, lowering investments and consumption (Anderson, 2006). higher costs of goods, lower consumption and less economic activity are undesired effects from sustained high inflation, therefore policy makers aim to sustain low rates.

The following section presents the motivation for the prominence of what we hypothesise has been the four main drivers of inflation since the beginning of the Covid-19 pandemic. Then, later in Section 3.3, we explain how these drive inflation through the perspective of the NKPC.

3.2 Current Drivers of Inflation

3.2.1 Government Spending

The first of four current relevant inflation drivers is government spending. Standard new Keynesian theory suggests that increased government spending is positively linked to private consumption, economic activity and inflationary pressure. Furthermore, Caldara & Kamps (2008) found empirical evidence supporting this relationship.

The Swedish government has implemented economic measures worth 400 SEK billion to dampen the effects of containment policies during the covid-19 pandemic. Financial aid has been given to companies, tax reductions have been implemented, and unemployment benefits have increased (Swedish Ministry of Finance, 2021a). The budgetary measures taken during 2020 and estimated to be taken during 2021 made up 8.5% of 2020's GDP, with the largest shares going to the short-term work scheme and reorientation support, making up 1.2% and 1.1% respectively (OECD, 2021). The short-term work scheme, which included wage subsidies and economic support to firms, cost the government 35.1 billion SEK in 2020 and 13.2 billion SEK in 2021 (Swedish Ministry of Finance, 2022).

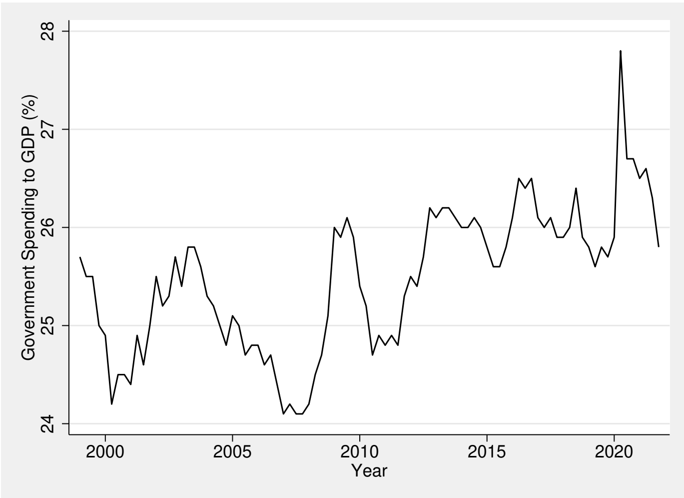

Figure 3: Government Spending to GDP (%)

Source: Eurostat

The increase in government spending in relation to GDP is displayed in Figure 3. It is clearly shown that the share of GDP related to general government spending has increased in the face of the covid-19 pandemic, from slightly below 26% ing 2019 to almost 28% in the second quarter of 2020. Government spending to GDP has decreased since the peak in 2020 and returned to pre-pandemic levels in the last quarter of 2021. Still, spending remained historically high from the second quarter of 2020 to the third quarter of 2021.

Fiscal spending has played a greater role during the recent crisis than in earlier ones. Without financial support, companies would have paid a greater cost, and fewer people would have stayed employed. Although fiscal measures have consisted of both tax breaks and government grants, the proportion of money spent on grants has been significantly larger than that on tax brakes (Swedish Ministry of Finance, 2021a).

3.2.2 Energy Price Hike

The second current relevant inflation driver is energy prices. Energy prices are included in the Consumer Price Index with Fixed Rates (CPIF), which is the measure that the Sveriges Riksbank uses for inflation targeting, meaning that an increase in energy prices would imply an direct increase in the consumer price basket (Sveriges Riksbank, 2022a). Moreover, according to (Bjellerup & Löf, 2008), increased production costs pushed on to the consumers is another way energy prices can cause inflationary pressure.

As the world has a growing population with an increasing demand for energy and as a greater concern for the consequences of global warming exist, the world has been struggling to find new sustainable energy sources. This development has been prominent as the world (Sweden in particular) is faced with an energy shortage. Moreover, energy prices have been affected by the great increase in demand for energy as society has opened up after Covid-19. As demand was low during the pandemic, many energy producers who decreased their production were not ready to match the sudden surge, causing a market disequilibrium with raised prices (Energimyndigheten, 2021). There is a current political debate concerning what is the cause of this. Some sides blame governments incapability to transition from fossil fuels to renewable energy sources or debate whether to expand nuclear energy or not (Nordhaus, 2021). Some also blame the EU's emission trading system for rising prices as it is too inefficient because of lousy regulation and speculation (Ainger, 2021).

Whatever the cause of the energy crisis is, it has resulted in an energy price hike that has put both firms and households under severe economic pressure. Sweden is not that dependent on natural gas but is still affected by the high prices. This is due to Sweden being interwoven with the rest of Europe, who are heavily dependent on it (Energimyndigheten, 2021). The development of natural gas prices is presented in Figure 4, which plots an index incorporating European, Japanese and American natural gas price indexes, where the recent hike is visible.

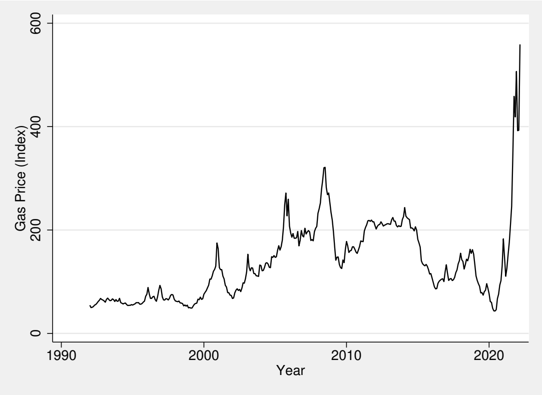

Figure 4: Natural Gas Price Index (monthly)

Source: IMF

Figure 5: Monthly average electricity price per kWh (excluding taxes)

Source: Statistics Sweden

There has also been a significant increase in gasoline prices recently. This is mainly due to an increase in the oil price itself and the high carbon tax and VAT that follows. This development led the Swedish government to decide to implement subsidies for large house owners and lower petrol taxes (Government Offices of Sweden, 2022). The evolution of the electricity price for a standard price agreement for a one- or two dwelling house with electric heating (annual consumption of 20 000kWh) is plotted in Figure 5.

3.2.3 Supply Chain Disruptions

The third recent inflation driver is supply chain disruptions. A supply chain disruptions is a global trade disturbance which causes a missmatch between the supply and demand of goods, pushing up prices (LaBelle & Santacreu, 2022).

Starting with the travel restrictions implemented in response to the Covid-19 pandemic, the world has experienced severe supply chain disruptions and bottlenecks, creating a lack of products and inputs at all levels of supply chain. Celasun et al. (2022) and Bhushan & Struyven (2021) further elaborates on this, saying that as people have been kept away from consuming services due to restrictions, people have instead changed their consumption behaviour, leading to an increase in the demand for goods. This results in rigidities because the supply side cannot increase as fast as the demand side. As demand increases and supply stays the same, prices must inevitably rise and contribute to inflationary pressure. Moreover, the reports explain that some industries are also negatively affected by the supply side as shutdowns and labour shortages caused by the pandemic have led to disruptions in the supply chains. This further enhances the effect of rigidities as when the supply decreases, prices are driven up even more. The effect intensified when developed countries started to lift their restrictions and returned to their former consumption patterns. In contrast underdeveloped countries, whose industries are often part of the global value chain, remained unvaccinated and had to keep their restrictions (Nguyen, 2021). The demand-triggered disruptions phenomenon is displayed in Figure 6 for Swedish consumption behaviour. It is clearly shown that the consumption of goods recovered much faster than the consumption of services.

Figure 6: Final consumption expenditure (quarterly)

Source: Eurostat

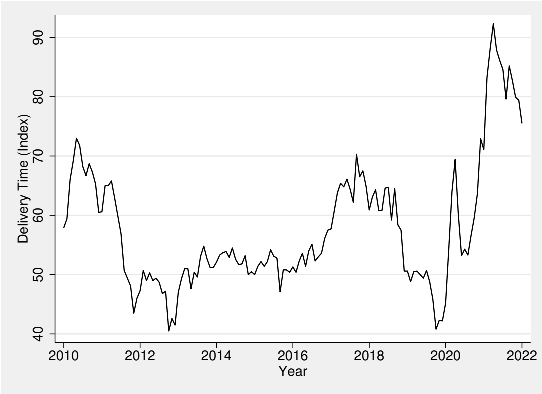

Figure 7: PMI suppliers' delivery times (monthly)

Source: Swedbank (2022)

The problem has become even more severe as bottlenecks appeared in several transport heavy sectors. For example, freight times have increased severely as ports worldwide have been overwhelmed by the increase in demand and a lack of sailor workers, making several transport routes for cargo ships blocked (Nguyen, 2021; Ellyatt, 2021). The development leads to a lack of goods and intensifies the distortions in the global value chains, leading to a further increase in prices. In Figure 7, the development of the subindex "Delivery times of Purchase Manager Index (PMI) - Manufacturing" is displayed (which also in turn is a subindex of the Global Supply Chain Pressure Index (GSCPI), which is one of the main variables in the estimations in this thesis). The subindex is an all-encompassing measure of delivery times of goods in all parts of the global value chain (Benigno, di Giovanni, Groen, & Noble, 2022). The index indicates significant increases in delivery times stemming from the Covid-19 pandemic.

3.2.4 Labour Market

The last inflation driver that we argue has been especially relevant during recent periods is the labour market, more specifically, labour market slack. Slack stems from the labour market and emerges when production is lower than capacity. Slack is inversely related to inflation, meaning that when slack is low and production exceeds capacity, pressure is put on the economy and prices are pushed up. Moreover, there are many ways of measuring the amount of slack in the economy (Barnichon & Shapiro, 2022).

The labour market has seen rapid changes recently, mainly due to the Covid-19 pandemic. Firstly, as displayed in Figure 9, the employment rate had slowly recovered from the great recession and persistently stayed around 68% prior to the Covid-19 crisis. As the crisis hit, the employment rate plummeted to 65.8% in June 2020 and stayed low for a prolonged period. The employment rate has since started increasing and has rebounded to higher levels than was seen pre-pandemic (68.2% in December 2021) (Statistics Sweden, 2022). Moreover, the period associated with the pandemic has seen higher labour market slack, according to a survey conducted by Eurostat (2022), than in 2019. Increased slack during this period is in line with the development seen in the employment rate.

When analysing the hours worked per employed person, see Figure 8, a slightly different development can be seen. During the peak of the covid-19 crisis, hours worked per employed person plummeted just as the employment rate. There is, however, a difference in the development of the recovery from the crisis, with hours worked not having rebounded in the same manner as the employment rate. When the employment rate increased to levels higher than pre-pandemic, hours worked did not. In fact, there has been a decrease in hours worked during the last quarter of 2021, implying that the historically high levels in the employment rate may have been due to low levels of hours worked per person employed. Nevertheless, the period associated with the covid-19 pandemic saw both low employment rate levels and, for people still employed, low levels of hours worked.

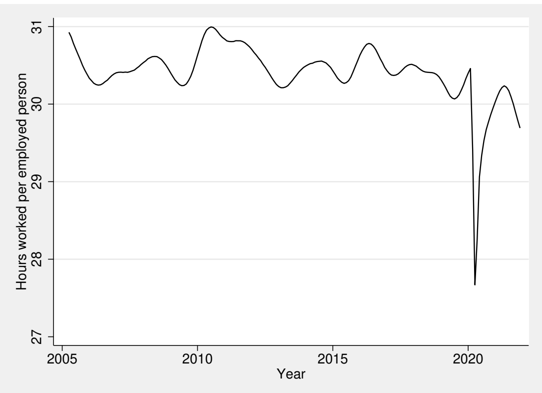

Figure 8: Hours worked per employed person

Source: Statistics Sweden & Authors calculations

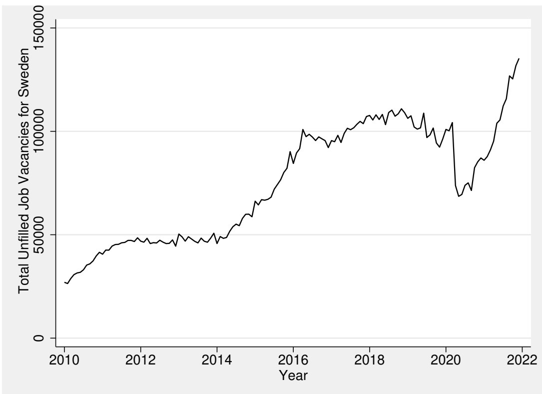

Figure 9: Total Unfilled Job Vacancies for Sweden, Persons

Source: Federal Reserve Economic Data (FRED) St. Louis

Recent disturbances in labour markets worldwide have most likely caused a structural

shift. For example, in the US, a phenomenon known as the Great Resignation is causing a tight labour market (Faccini & Miles, 2022). In the US, the job quitting rate is at an all-time high with a persistent upwards trend stemming from the early stages of the pandemic (Horowítz, 2022). Furthermore, Faccini & Miles (2022) argue that the high job-to-job switching rate seen during the pandemic causes high competition between employers, making them have to offer significantly higher wages to hire and keep employees.
Other structural disturbances seen in the Swedish labour market are high rates of unfilled job vacancies, displayed in Figure 9, contrasting the high employment rates. Combing of a highly employed population with relatively high negotiation power (relative to unemployed people) and many unfilled vacancies may cause competition between employers, making wages rise. Figure 10 shows that relative to 2020, 2021 has shown increased wages. However, this increase is similar to earlier years and may not display any abnormal wage development.

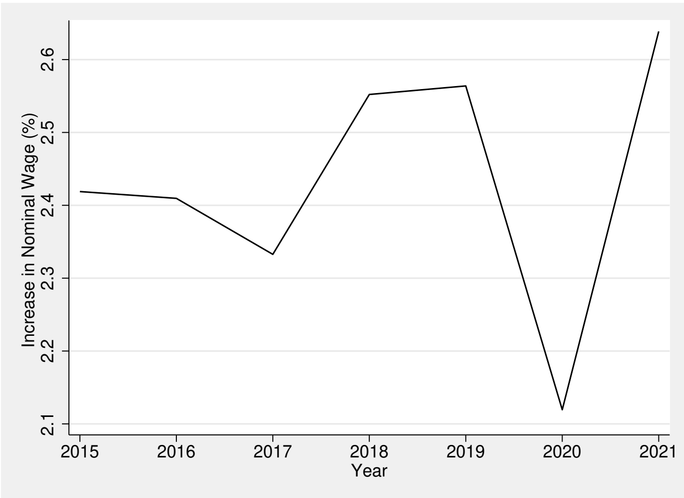

Figure 10: Yearly Increase in nominal wages (%)
Source: Medlingsinstitutet

3.3 The Extended New Keynesian Phillips Curve?

The following section attempts to derive an updated NKPC to properly incorporate the current drivers of inflation described in Section 3.2 and will be presented in Equation 3.

Firstly, the updated version still follows in the theoretical footsteps of Galı & Gertler (1999) and assumes that the NKPC with marginal cost included is favourable at explaining inflation in Sweden. Note however, that we will decompose marginal cost following Malikane & Mokoka (2014), where marginal cost consists of one labour market indicator, the output gap and the sum of different supply shocks (relative import, energy and food

prices). This study, however, assumes that there is another combination of supply shocks affecting inflation in Sweden in recent years. Therefore, motivated in Section 3.2, it includes variables that capture hikes in energy prices and the consequences of supply chain disruptions (the $\hat{S}_t$). Furthermore, instead of the regular usage of labour income share as a measure of labour market slackness, the employment-to-population gap (E*/P) is included. Moreover, the NKPC also includes the output gap ($\widehat{y}_t$).
Firstly, we substitute:

$$\widehat{mc}_t = \omega_y \widehat{y}_t + \omega_s \frac{\widehat{E_t^*}}{P_t} + \sum_{n=1}^{n} \omega_p \hat{S}_t$$

in to Equation 1.

Secondly, with some rearrangement, we end up with:

$$\pi_t = \alpha_b \pi_{t-1} + \psi_y \widehat{y} + \psi_s \frac{\widehat{E_t^*}}{P_t} + \sum_{n=1}^{n} \gamma_p \hat{S}_t \tag{3}$$

The careful reader may see that Equation 3 does not include inflation expectations. This choice was made following Rudd & Whelan (2005, 2006) to avoid biases. This is also due to the forward-looking aspect of inflationary behaviour not being the main target of this thesis and it diverting the focus of the other channels that we examine. Through the conclusions drawn from Sveriges Riksbank (2022c), who studied the effects of the recent surge in energy prices and inflation, it is argued that energy prices are positively linked to inflation in recent times. It is easy to see that an energy price hike will directly cause inflation as consumers spend an evident portion of their income on different forms of energy, giving it a significant share in the CPIFs. Anyhow, Sveriges Riksbank (2022c) explains how secondary indirect effects of raised energy prices may cause inflation, e.g. through the higher production costs of firms. The article tested the indirect and direct effects of higher energy prices on inflation. They did, however, not find any evidence for any indirect effects,

A similar study from Bjellerup & Löf (2008) did find evidence of indirect effects. The indirect effect found in 2008 was estimated to be of the same magnitude as the direct effect, the difference was that the indirect effect took a longer time to affect inflation. They emphasise that the effect is hard to measure and even if the energy price hikes are temporary, they may still contribute greatly to inflation if, e.g. households experience the inflation to be greater than in reality, it may cause even higher inflation through increased inflation expectations. We assume that although the recently published article did not find evidence for any indirect effect, it has now gone long enough for the marginal cost to be affected by increased energy prices, hence higher inflation. It is this partially indirect effect that we test for and that we assume is linked to the recent surge in inflation.

From LaBelle & Santacreu (2022), it is argued that recent shifts in consumption habits and containment policies, have caused a global supply chain disruption, which in turn is positively linked to inflation. Supply chain disruption causes higher costs of intermediate goods, increasing firms' marginal costs. They also describe how companies producing durable goods have become more attached to global value chains, making them vulnerable to foreign disruptions. They point out that the shocks to these supply chains during Covid-19 were under even more pressure as consumer demand switched from services to more durable goods. In addition, changed consumption behaviour was even more amplified by fiscal stimulus. Therefore, supply chain disruptions are the other supply shock making up marginal cost.

The Labour Market shock is measured through changes in labour market slackness. Faccini & Miles (2022) argue this point, that labour slack is inversely related to wage-related inflation, and that the inflationary pressure from a Labour Market shock goes through this channel. They oppose using the standard measure of unemployment to measure the inflationary pressure stemming from labour market slack. The authors explain that the unemployment rate neglects the impact of the already employed people have on the labour market and emphasise how job-to-job mobility can increase wage competition. Barnichon & Shapiro (2022) examines what is the best measure of economic slack, i.e. an economy's unused capacity to forecast inflation and finds that the types constructed to measure labour market tightness perform the best. Therefore in line with Howard, Rich, & Tracy (2021), this thesis will measure labour market slack by an employment-to-population gap, which will be denoted as E*/P for the rest of this thesis. In addition to this, the output gap will be included to capture the excess unused economic capacity that occurs independently of what happens in the labour market.

The last shock that will be analysed is a government spending shock that increases inflation through the output gap. Caldara & Kamps (2008) analysed the effects of government spending and tax shocks on macroeconomic variables. Their result follows what the conventional textbook New Keynesian model suggests, that increases in private consumption are assumed to be positively associated with inflation when government spending increases.

However, this relationship has been tested in recent years. Monetary policymakers have been faced with the challenge of a ZLB and entered a liquidity trap where traditional monetary policy has become ineffective. Christiano, Eichenbaum, & Rebelo (2011) explain that the fiscal multiplier should be large during these circumstances. When government spending is imposed, output, marginal cost and expected inflation all increase, which drives the real interest rate down. In turn this increases private consumption and consequently gives rise to more output, marginal cost and expected inflation.

In contrast, Jørgensen & Ravn (2022) tested the relationship and concluded that government spending has a non-existent and at times, negative effect on inflation. The authors explain this by including total factor productivity in the New Keynesian model. Then, as government spending increases, firms will increase their productivity to face the surge in consumer demand. If this effect is sufficiently powerful, it can outweigh the pressure higher wages have on marginal cost and thus decrease it. In turn, firms can reduce their prices, resulting in lower expected inflation, giving rise to a smaller fiscal multiplier. Government spending has been exceptionally high recently, therefore it is assumed that it will play a prominent role in recent inflation dynamics and, due to the liquidity trap and the recession during the Covid-19, might cause disinflationary behaviour.

4 Data

This section contains data descriptions and information on how we calculated the model variables. All the data used are in quarterly frequency and span from the first quarter of 2000 to the last quarter of 2021. The variables included in our regressions are: the Output Gap, Inflation, the Domestic and Foreign Monetary Policy Rates, Government spending-to-GDP, employment-to-population gap (E*/P), The Exchange Rate, Supply Chain Disruption and Energy Price.

In the following paragraphs, all of the variables are presented and explained. Many of them have been detrended using a HP-filter to remove underlying trends and turn them in deviation from their steady-state. Moreover, the HP-filter makes sure that the variables are stationary, a necessary condition for our VAR model. Appendix A provides data sources and further information on the variables.

Output Gap ($\hat{Y}$) is measured as the difference between actual and potential GDP. GDP is seasonally adjusted and potential output is measured using a HP-filter, following the methodology suggested by the Swedish Ministry of Finance (2021b).

Inflation ($CPIF$) is measured with CPIF, which is the aggregated consumer prices over time in Sweden and it is the one used by the Swedish Riksbank for the inflation target. Compared to conventional Consumer Price Index (CPI), CPIF excludes varied mortgage rates, that are favourable for central banks to use. Mortgage rates are included in the CPI, making the direct effects of changed interest rates deceptive. The drawback of CPIF is that in compared to the Harmonized Consumer Price Index (HCPI), it does not have harmonized measurement procedures, making it less than ideal for cross-country comparison. This thesis only focuses on the Swedish inflation rate, hence, this will not be an issue. The index has been transformed by first using the natural logarithm and then taking the first difference, giving us the annual percentage change. Moreover, the annual percentage change has been detrended using a HP-filter.

Domestic Monetary Policy (INT_d) is measured as the main policy rate by Sveriges Riksbank, the repo rate. Furthermore, the repo rate has been detrended using a HP-filter. This way of calculating the policy rate follows Corbo & Di Casola (2022).

Government Spending (GS) Government spending is measured as the final consumption expenditure of the general government in proportion to GDP. We chose to use data for spending-to-GDP because it better represents the severity of governmental spending. Moreover, if we had not used spending in proportion to GDP, then, when we enter a deep recession and large fiscal packages are employed, they will not show up as clearly. Furthermore, the series has been detrended using a HP-filter.

Labour Market (LM) will be measured with E*/P following Howard, Rich, & Tracy (2021) as discussed in Section 3.3. The employment-to-population gap (E*/P) is calculated using a HP-filter.

The **Exchange rate** (KIX) is represented by the krona index (KIX) which is the SEKs exchange rate to Sweden's 32 biggest trading partners. It assumed that Sweden is a SOE, making the outside world affect the Swedish economy but not the other way around. Therefore, it is unrealistic not to take into account the eventual effect depreciation or appreciation of the SEK has on domestic inflation due to changes in trade flows. Therefore, data has been transformed using the natural logarithm and taking the first difference, giving us the annual percentage annual change. The same methodology of calculating the exchange rate was used by Corbo & Di Casola (2022).

We used the same methodology when calculating **Foreign monetary policy** (INT_f) as we did for **Domestic Monetary Policy**. The reasoning behind why we choose to include this variable is the same as for the **Exchange rate**, that Sweden is a SOE. However, the main policy rate for the ECB has not been the same during the period that we analyse. Therefore, the European Central Banks:s (ECB) 3-Month Rates and Yields: Interbank Rates for the Euro Area (EURIBOR) have instead been chosen to serve as a proxy as it follows main policy rate for the ECB and is continuous over the whole time period.

Supply Chain (SC) is measured by the GSCPI, as estimated by Benigno et al. (2022). GSCPI is an aggregated index using different sub-indexes that measure raw material shipping costs, container shipping costs, air transportation freight costs and how manufacturing industries perform in global value chains. All the data is thereafter weighted such that the larger GDP the country has, the more it is represented in the GSCPI. The index has been transformed to natural logarithms and then taken the first difference to get the percentage annual change.

Energy prices (P_{energy}) are measured using the "Energy" special aggregate from HICP. It includes all of the sub-indexes from HICP related to "energy", such as electricity, gas, different fuels, heat and "Fuels and lubricants for personal transport equipment".

All of the variables used in the model are necessarily stationary. Given that we use two lags in our estimation, the Dickey-Fuller test for a unit root is performed using two lags. The null hypothesis of a unit root could be rejected for all of the variables using two lags. Moreover, the Phillip-Perron test came to the same conclusion. Although all data series are stationary at two lags, they may still contain autocorrelated error terms at this lag length. Autocorrelation at this lag length would imply that the unit root test results are not to be trusted. Moreover, autocorrelation in the error terms at the chosen lag length would imply that the results for the specifications above may be spurious, causing standard errors to be small and the fit to be exaggerated (Enders, 2014). Using the Portmanteau test for white noise, at the lag length of two, none of the variables allowed us to reject the null hypothesis, meaning that none of the data series exhibited autocorrelated error terms. Appendix D presents plots of the developments of all the variables.

5 Methodology

This section describes the theory and the implementation of our empirical method, the structural vector autoregression model with Bayesian estimation.

5.1 Structural Vector Autoregression

5.1.1 Theory

Following other scholars, Corbo & Di Casola (2022), Caldara & Kamps (2008) and Osorio & Unsal (2013), we make use of vector autoregressive (VAR) models to analyse the interrelationships between the variables described in Section 3.3. The advantages of using a VAR as opposed to other econometric methods are that a VAR can distinguish between effects going both ways. That is, it can distinguish between the direct effect coming from one variable to the other one and the feedback effect coming from the other one. VAR models also have a wide support within the econometric and the policymaking communities. Other well-established methods for explaining inflationary dynamics are the DSGE models, often used by Sveriges Riksbank and the National Institute of Economic Research when they conduct economic analysis. Even though the DSGE models are better at simulating policy implementations, the SVAR allows us to estimate the magnitudes of the response to macroeconomic shocks using historical data. Therefore, the method chosen for this thesis, as its purpose is to estimate the weight each shock contributes to the recent inflation developments, is the VAR.

Estimations are done using the Bayesian Estimation, Analysis and Regression (BEAR) toolbox from the European Central Bank. The theoretical framework for the toolbox is described in Dieppe, Legrand, & Van Roye (2016), whose theories applicable to our research follow Doan, Litterman, & Sims (1984) and Litterman (1986). We have not chosen the mean-adjusted VAR used by Corbo & Di Casola (2022) and suggested by Villani (2009) as we did not have sufficient information on steady-state priors for it to make a significantly better estimation.

The VAR model with n endogenous variables, p lags and a constant can be written in the following way:

$$y_t = c + B_1 y_{t-1} + B_2 y_{t-2} + ... + B_p y_{t-p} + \epsilon_t \quad \epsilon_t \sim \mathcal{N}(0, \Sigma_n) \quad t = 1, ..., T \tag{4}$$

Firstly, the model contains n endogenous variables in the n x 1 vector $y_t = (y_{t,1}, ..., y_{t,n})'$ and c is an n x 1 vector of constants. We have chosen to include a constant as, although the variables are mean-reverting (stationary), they may not revert to zero, an effect the constant captures. The p matrices $(B_1, ..., B_p)$ contain all of the reduced-form estimates and are n x n. The error term ϵ_t is an n x 1 vector $\epsilon_t = (\epsilon_{t,1}, ..., \epsilon_{t,n})'$ containing all of the error terms and follows a multivariate normal distribution with Σ_n having variances on the diagonal and covariances on the off diagonal.

Equation (4) displays a general representation of a VAR model. We have chosen to include $n = 9$ and $p = 2$ in our main estimation. The lag length $p = 2$ was chosen following Corbo & Di Casola (2022), who also estimated a BSVAR for Sweden. Other scholars, such as Blanchard & Perotti (2002) and Caldara & Kamps (2008), recommend using a lag length $p = 4$ when working with quarterly data. However, this recommendation is not Sweden specific, hence $p = 2$ in our model. The $n = 9$ variables are described in Section 3.3.

The VAR representation in equation (4) has cross-correlated error terms, meaning that they do not display the individual shocks, which is of our interest. To correctly assess each variable's interrelationships and responses of to a shock in another, the structural components need to be identified. The SVAR representation in equation (5) allows for error terms to represent the structural and "unclouded" shocks. This representation, as opposed to the reduced-form, has theoretical meaning, but we cannot run this model due to the unit coefficient to the left of y_t. We need to trace the model in equation (5) through estimation of equation (4). Equation (4) contains fewer estimated parameters than equation (5), implying that we need to put some restrictions on equation (5) to retrieve it. There are several methods of identification/restriction, but we chose to implement SZR, discussed in Section 5.1.2.

$$A_0 y_t = C + A_1 y_{t-1} + ... + A_p y_{t-p} + v_t \quad v_t \sim \mathcal{N}(0, I_n) \quad t = 1, ..., T \tag{5}$$

v_t represents an n x 1 vector of structural innovations with a mean of zero and a variance-covariance matrix of I_n. A structural decomposition of the reduced-form matrices can be represented as $B_j = A_0^{-1} A_j$, $C = A_0^{-1} c$ and $\epsilon_t = A_0^{-1} v_t$. I_n only contains zeros off the diagonal, implying that the shocks in the model are uncorrelated and appear independently from each other. Therefore, the SVAR gives us the structural shocks in v_t.

Moreover, the parameters in equation (4) are estimated using Bayesian methods. As Bayesian, we are interested in the probability distribution of the model parameters given the sample data, formally known as the posterior. In our estimations, the parameters are estimated as the median of the posterior. The posterior is made up of the likelihood function and a prior distribution. The data give the likelihood function, but to retrieve the posterior, we also need to identify the prior distribution. To do this, we use Litterman (1986) method, Minnesota priors. Moreover, the advantage of using Bayesian methods as opposed to frequentist is that we do not have to worry about overparameterization, that the estimates are too dependent on the sample data and do not represent the population. A detailed description of how we implement Bayesian methods and make use of Minnesota priors can be found in Appendix B. We highly recommend the reader to read this part as it helps with the intuition going forward.

Given the reduced-form estimates and restrictions on the structural matrix A_0, it is possible to retrieve the SVAR in equation (5).

5.1.2 Identification

As mentioned earlier, restrictions need to be put in place to identify the SVAR in equation (5). The restriction method used is the SZR approach suggested by Arias, Rubio-Ramirez, & Waggoner (2014). This approach was used by other scholars, such as Corbo & Di Casola (2022), trying to identify structural shocks for small open economies. The restrictions are summarized in Table 1. The benefit of using the SZR approach is that we can put restrictions on the Impulse Response Functions (IRF) of the variables for several periods (although we exclusively enforce restrictions on impact). Given restrictions on the IRFs, we can distinguish between different types of shocks through different responses (SZR responses). Given that we restrict the variables put into the VAR to react positively, negatively or not at all to a shock, we can extract the structural component related to that particular shock. The ability to extract exact shocks through restriction on the responses is beneficial as it allows us to do a more specific analysis of the aspired shocks.

Other identification approaches exist, such as the recursive approach suggested by Sims (1992) or the non-recursive approach suggested by Blanchard & Perotti (2002). These approaches, however, do not allow for restriction on the impulse responses and do therefore not allow us to identify specific shocks. That is, they do allow us to extract the structural shock related to a specific variable, but the identification does not allow restriction on what structural component of the identified shock.

The implementation of SZR is done using Algorithm 4, section 3.6 in Arias, Rubio-Ramirez, & Waggoner (2014). The algorithm, described broadly, draws a vector of random parameter values from the specified posterior above. Firstly, the algorithm tests whether the vector drawn satisfies the zero restrictions. If it does, then it test whether the parameters drawn subject to sign restriction are of the same sign as the restriction put in place. If the draw satisfies both conditions, it is kept, otherwise it is discarded. This is done until the required amount of draws from the posterior has been accepted. Following Corbo & Di Casola (2022), the estimation results are based on 1000 accepted draws from the posterior with a burn-in of 100 (burn-in is the initially discarded draws).

5.2 Implementation

The following section discusses how we implement the BSVAR discussed above. The section contains three parts, a description of the three outputs that the BSVAR gives and which we intend to analyse, implementation of block-exogeneity and the SZRs we put in our model.

5.2.1 Tools of Analysis

Three outputs used to analyse the results given by the SVAR are IRFs, HDs and FEVDs, all of who follow Dieppe, Legrand, & Van Roye (2016). Moreover, all of the three tools described below rely on the identification of the structural shocks given by the SVAR.

Staring with **IRF**, given a one-time shock to variable i at time t, the impulse responses then calculates the change in movement over time of variable j, assuming that variable j starts at its steady-state (Starting at its mean). The magnitude of the shock is estimated by the structural shock stemming from the SVAR model. Given the structural shock and the structural parameters deciding the relationship of one variable to its own lags, the whole course of movement from the structural shock can be estimated. The impulse responses are helpful as it allows us to analyse the dynamic given individual shocks to the economy. [1]

Moving on to the **HD**, broadly, HD computes the historical contribution of all structural shocks i to movements in variable j. That is, the sum of all shocks i and the estimated impulse responses of variable j to these shocks allow us to quantify how much of the movement in variable j at time t contributes to the different structural shocks. The decomposition at time t does not only depend on the contemporaneous shocks but the whole history of shocks $\{t-1, ..., 0\}$ and their estimated effect on variable j at time t.

Lastly, we make use of **FEVD**. Firstly, an estimation of the n-step ahead forecast errors is computed. The forecast errors are the sum of the future structural shock and their impact on variable j at horizon h. Secondly, given the variance in the forecast errors, the variance in the estimated future structural shocks and their impact on variable j, we can compute the share of variance in variable j due to the variance in each structural shock. The advantage of FEVD is that it gives us information on what drives future expected movement in variable j, for us inflation. The disadvantage is that it relies on the strength of the forecast, meaning that a poor forecast creates unreliable FEVD.

5.2.2 Block-exogeneity

Another methodology used to assess the relations intended in this thesis properly is block-exogeneity. Block-exogeneity allows us to specify exogeneity more appropriately in the model. Furthermore, using block-exogeneity, in contrast to adding them as strictly exogenous variables, allows us to break out the structural components for these exogenous variables, which are necessary for the HD and FEVD.

The methodology goes as follows. We define y_2 as the endogenous block and y_1 as the exogenous block. All variables within y_1 are endogenous to all other variables in y_2 and to all variables in y_1. All variables in y_1 are exogenous to the whole y_2 block and to all other variables, all but itself in y_1. Setting the matrices of parameters in position 1,2, $A^1_{1,2}$ and $A^2_{1,2}$, in (11) equal to zero implies all variables in y_1 being entirely exogenous for y_2.

$$\begin{pmatrix} y_{1,t} \\ y_{2,t} \end{pmatrix} = \begin{pmatrix} A^1_{1,1} & 0 \\ A^1_{2,1} & A^1_{2,2} \end{pmatrix} \begin{pmatrix} y_{1,t-1} \\ y_{2,t-1} \end{pmatrix} + \begin{pmatrix} A^2_{1,1} & 0 \\ A^2_{2,1} & A^2_{2,2} \end{pmatrix} \begin{pmatrix} y_{1,t-2} \\ y_{2,t-2} \end{pmatrix} + \begin{pmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \end{pmatrix} \quad (11)$$

[1] The IRFs are displayed in Appendix C, and we will not further elaborate on what they imply as the results for the HD and FEVD give us much more empirical information to analyse

with:

$$y_t = \begin{pmatrix} y_{1,t} & y_{2,t} \end{pmatrix}'$$

The variables included in the endogenous block y_2 are the inflation rate, the output gap, the domestic policy rate, government spending, the employment-to-population gap and the exchange rate. The variables included in the exogenous block y_1 are the foreign policy rate, global supply chain disruptions and energy prices.

The matrices in position 1,1, $A^1_{1,1}$ and $A^2_{1,1}$, contains the parameters regarding the relationship between the exogenous variables. In these matrices, using the same procedure as when dealing with the block representation, the parameters deciding the effect of a shock on another are all set to zero. This adoption allows us to estimate the model with the exogenous relations we assume to exist. To ensure that the parameters we assume to be zero actually become zero, we use the Minnesota priors with an added hyper-parameter, block-exogeneity shrinkage λ_5, which is set to 0.001. The hyper-parameter is implemented in the variance-covariance matrix of the prior distribution (see (8)). Setting the variance for these parameters to an arbitrarily small value implies that they shrink to the mean, which is set to zero.

5.2.3 Sign and Zero-restrictions

The following section discusses the SZRs put into the SVAR to identify it correctly. All of the reactions to all shocks are restricted using SZRs and are displayed in Table 1. Most implemented restrictions are not controversial and are based on general New Keynesian theory (for example, see Forbes, Hjortsoe, & Nenova (2018)). Moreover, most of the restrictions put in Table 1 follow other scholars such as Corbo & Di Casola (2022), Jovičić & Kunovac (2017) and Caldara & Kamps (2008). It is assumed that Sweden is a SOE and is affected by global shocks, but that Sweden is unable to have any effect on global factors. Therefore, zero restrictions are used to impose no response of foreign variables to domestic shocks.

Furthermore, Energimyndigheten (2022) explains that the Swedish energy market is integrated with the global (mainly European) one, therefore, a large portion of domestic prices are determined by the demand and supply in other countries. Furthermore, they also highlight that another significant determinant of energy prices is weather development, a utterly exogenous factor. Therefore, zero restrictions are also imposed on the responses of energy prices.

Table 1: Identification restrictions

shock/variable	$\hat{Y}$	$CPIF$	INT_d	GS	LM	KIX	INT_f	SC	P_{energy}
Endogenous shocks									
Business cycle	+	+			+		0	0	0
Inflation		+	+				0	0	0
Monetary Policy	−	−	+			−	0	0	0
Government expansion	+			+	+		0	0	0
Labour market	+	+			+		0	0	0
Exchange rate						+	0	0	0
Exogenous shocks									
Monetary Policy						+	+	0	0
Supply chain	−	+					0	+	0
Energy price	−	+		+	−		0	0	+

Notes: (+) = positive sign, (–) = negative sign, (0) = zero contemporaneous effect and blank indicates unrestricted

Firstly, each shock is assumed to affect itself positively, hence (+) on the diagonal. Secondly, we now proceed to explain the economic reasoning behind each restrictions, starting with the business cycle shock and ending with the energy price shock. Thirdly, due to uncertainty about the empirical results related to the exchange rate, a discussion for all restrictions that have to do with the exchange rate (both its response to other shocks and others' response to an exchange rate shock) have been moved to the last bullet point. Fourthly, we will not comment on the zero restrictions put into the table other than that all exogenous variables never react to any shock except for the one corresponding to themselves.

- A business cycle shock is assumed to increase inflation, as stated by the NKPC, hence (+).
- A business cycle shock is also assumed to increase economic activity, requiring firms to employ more people, increasing LM, hence (+).
- While the Federal Reserve's (FED) task is to enhance economic performance and fight unemployment, this is not the case of the Swedish Riksbank who sticks to focusing on maintaining monetary stability, hence no restriction.
- Moreover, we assume that the Swedish Riksbank follows the Taylor rule and raises the nominal interest rate in response to an increase in inflation, hence (+).

- The monetary policy shock in the form of interest rates is assumed to incentivise savings and lower economic activity, making both the output gap inflation react negatively, hence (-).

- The responses to a foreign monetary policy are left entirely unrestricted as its effects domestic variables are rather unclear with a binding ZLB. Moreover, the responses align with earlier studies on which this thesis is based on.

- It is assumed that a government spending shock stimulates economic activity and increases the short term output, pushing up the output gap, hence (+).

- The unrestricted response of the government spending shock to inflation is noteworthy as New Keynesian theory suggests it to be positive under normal circumstances. However, as discussed in section 3.3, when faced by the ZLB, higher government spending may cause a disinflationary response. Our sample includes periods with and without ZLB, hence unrestricted.

- Moreover, we assume that a government spending shock increase LM due to increased economic activity demanding more labour. This is entirely in line with new Keynesian theory, hence (+).

- Furthermore, we assume that a labour market shock implies an increase in the usage of labour inputs, which implies greater economic activity. Note that a shock to the labour market implies a decrease in slack (due to our measure of labour market slack, E*/P). More economic activity implies a positive response to the output gap, hence (+).

- From the motivation in 3.3, inflation is negatively related to Labour Market slack. A shock to the labour market, which is a negative slack shock, is therefore assumed to make inflation react positively, hence (+).

- Both the supply chain and the energy price shocks are assumed to be a part of the extended NKPC and are assumed to affect inflation positively, hence (+).

- Moreover, higher energy prices are assumed to increase the cost of production and supply chain disruptions are assumed to cause higher prices for intermediate goods. Therefore, they are positively related to firms marginal costs and negatively related economic activity and the output gap, hence (-).

- In contrast to the response of the output gap and inflation, these two shocks differ regarding government spending and labour market activity. Firstly, the Swedish government may increase spending in reaction to higher energy prices to compensate the people who are especially affected by them, hence (+). Secondly, high energy prices are costly for firms and they are therefore less able to use labour inputs, making LM decrease, hence (-).

- On the other hand, the responses of government spending and the labour market to supply chain disruption are less clear. Supply chain disruptions may cause firms to need governmental support, but they may also not cause any reaction at all. The same goes for the labour market as it may cause layoffs due to increased costs, but it may also force firms to hire more workers to deal with the disruption issued. It is important to remember that the disruption is partly demand-driven, meaning that an increase in demand for goods causes a demand for more labour inputs. Therefore, we put no restriction on either of the responses to a supply chain disruption shock.

- Many other studies that have conducted similar analyses have incorporated the exchange rate, but their restrictions on its relationships have often differed (Scholl & Uhlig, 2008; Fisher & Huh, 2016; Bjørnland & Halvorsen, 2014). Authors that study the effects of monetary policy on exchange rates place their restrictions using an "agnostic" approach (that is, they leave them unrestricted). Scholl & Uhlig (2008) found in a study examining the exchange rate and monetary policy that when interpreting their results, they were met with a "price puzzle", meaning that the results were significantly different from conventional macroeconomic theory. To combat this, the study imposed no restrictions on the responses of the variables from an exchange rate shock, hence, neither do we. Moreover, following Bjørnland & Halvorsen (2014), we impose the restrictions that increased domestic policy rates imply an appreciation and an increased foreign policy rate causes a depreciation. Note that an appreciation corresponds to a decrease in KIX whilst a depreciation corresponds to an increase.

6 Results

The results section is structured as follows. Firstly, the historical development of inflation drivers is displayed and analysed. Secondly, recent development is discussed, starting from the first quarter of 2019 to the fourth quarter of 2021. Thirdly, an analysis of future contributions to movements in inflation is conducted. [2]

6.1 Historical Decomposition

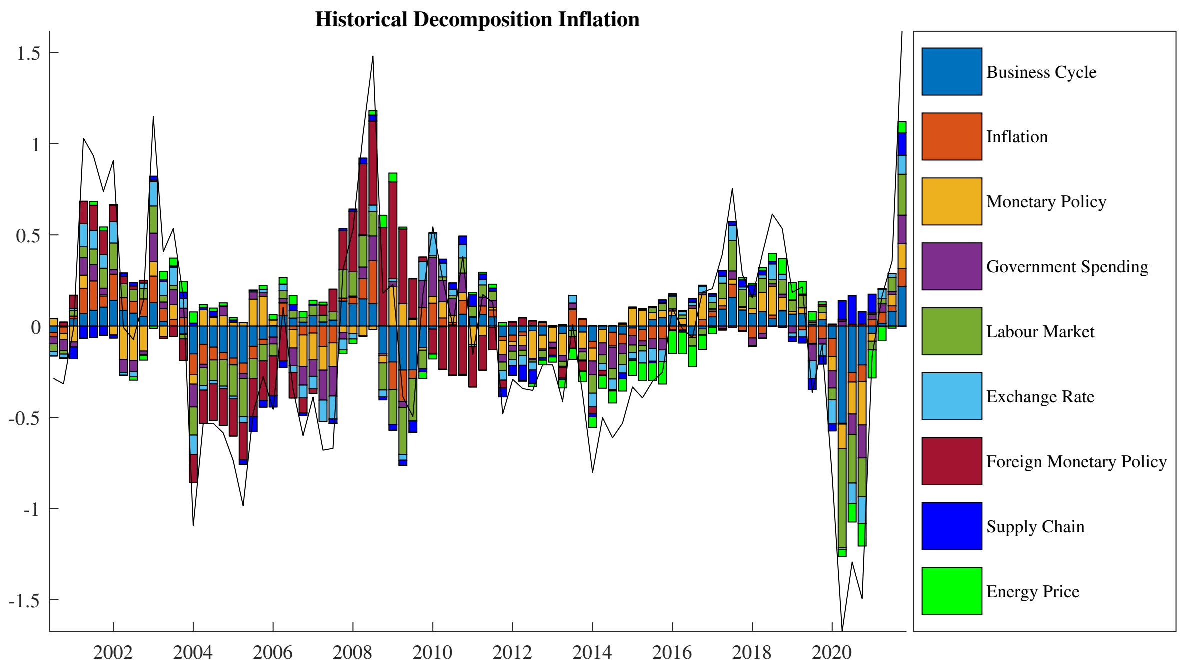

Figure 11: HD from the main model of CPIF Inflation, year-on-year changes in deviation from the steady-state.

Note: For an interpretation of the reference to the colors of this and following figures, the reader is referred to the online version of this thesis.

Figure 11 illustrates the magnitudes and contribution of each shock to deviations of inflation from its steady-state from the third quarter of 2000 to the last quarter of 2021 (note that there are no estimates for the first two quarters of 2000 as the VAR include two lags). As Figure 11 indicates, the Output Gap shock and the Labour Market shock have been the overall greatest contributors to developments of inflation variations. Furthermore, Government Spending, Monetary Policy and Inflation shocks have had a more modest contribution, whilst supply chain, energy price and exchange rate shocks have been the

[2] Again, the results for the IRFs are in Appendix C for the interested reader. The IRF gives us less information to analyse and including them here would only divert to focus of the HD and FEVD

least driving factors. Note, however, that these results are general, and some periods may exhibit more prominent roles for the different channels (See energy price shocks from 2014 to 2017 in Figure 11). Most of the variables mentioned have contributed both negatively and positively and have been relatively present over the whole period. Moreover, Labour market shocks seem to have been especially prominent during more volatile periods. A notable shift in the development of the main contributors to inflation occurred during the stable period between 2012 and 2017. Foreign Monetary Policy was one of the main determinants in the highly volatile period before (during the great recession) but has seen close to no contribution afterwards.

Foreign monetary policy, measured with EURIBOR, not having any significant contribution to inflation movements after 2012 is most likely due to the ZLB. EURIBOR started to come close to zero around 2012, and in 2015 it hit zero (FRED St. Louis, 2022). The result that foreign monetary policy stopped affecting inflation around this time makes sense as the rate barely moved from this point forward and due to ZLB making any changes in the policy rate ineffective. A more detailed discussion on the effects of ZLB on the other variables is held in Section 7.2.

Furthermore, our findings suggest that domestic monetary policy never stopped contributing to movements in inflation, even for periods where the ZLB was binding. This result is in line with (Corbo & Di Casola, 2022), who also found empirical evidence that monetary policy shocks still contribute to inflation movements during ZLB. Moreover, both the direction of the historical contributions and the decrease in magnitude after the great recession follow their results.

To no surprise, the output gap moved cyclically to inflation and was a large and persistent driver. The output gap and the labour market measure moving cyclically and being persistent determinants of inflation suggest that the NKPC, more specifically the NKPC including marginal cost, has been relevant in explaining inflation throughout the sample. Moreover, the relationship suggested by the NKPC has not stagnated or decreased in recent times. In fact, the relationship has been more prevalent during the pandemic than in earlier periods. Our results suggest that the highly discussed idea of a flattening of the NKPC, can generally not be seen (Kuester, Müller, & Stölting, 2009). Although, during the period from 2012 to 2016, the relationship was more muted. It could be that periods related to low inflation volatility and economic stability, such as the period 2012 to 2016, imply a less prevalent NKPC. Moreover, our results are quite dependent on the choice of marginal cost, more specifically, our choice of labour market measure, E*/P. If we were to use another measure, such as the unit labour cost used by Galı & Gertler (1999), our results might have differed. We are, however, standing by our choice of E*/P as it is assumed to better capture modern wage dynamics (Howard, Rich, & Tracy, 2021). The persistent cyclical behaviour of inflation to its own shock implies that earlier inflation affects future inflation, implying that the inclusion of lagged inflation in the NKPC is not redundant.

Another conclusion drawn from our results is the relatively low contribution of the exchange rate to movements in inflation. This is in stark contrast to Corbo & Di Casola (2022) who found larger contributions throughout their sample. The difference may be due to us including other variables (such as the four suggested channels) and us not putting any restrictions on the responses of the variables to an exchange rate shock. We stand by our choice of a less restrictive approach due to the price puzzle. Moreover, the difference in results may be due to us including both the foreign and the domestic policy rate and their co-joint relationship to the exchange rate. Furthermore, the exchange rate having a low contribution suggests that although Sweden is an open economy (strengthened by the effect that foreign monetary policy has historically had on inflation), foreign inflationary pressure is not mainly driven by changes in the exchange rate.

Government spending moved cyclically to inflation up until around 2012. After 2012, government spending moved both cyclically and counter-cyclical to inflation, meaning that the sign of the effect of a government spending shock was less clear after this period. The counter-cyclical behaviour seen during these periods is most likely due to the fiscal multiplier being much lower during ZLB (Jørgensen & Ravn, 2022; Choi, Shin, & Yoo, 2022).

Energy prices had mostly a negligible effect on inflation, other than for the period 2015 to 2017. The deflationary effects seen during this period are in line with the reports of Hirth (2018), who suggest that the prices were low due to price and volume shocks.

Supply chain shocks have historically been the lowest contributor, although, for a brief period after the great recession, it did cause disinflationary pressure. This result is in line with the data, which suggests a drop in pressure, making overseas trade easy and cost-effective.

6.2 Determinants of Inflation During the Pandemic

Table 2: Yearly Contributions to Inflation Deviations from its Steady State, Main Estimation (percentage points)

	Normal values			Absolute values		
	2019	2020	2021	2019	2020	2021
Total deviation	0.08	-1.23	0.59	0.22	1.23	0.62
Endogenous shocks						
Business cycle	0.04	-0.27	0.07	0.04	0.27	0.09
Inflation	-0.05	-0.06	0.06	0.05	0.06	0.06
Monetary Policy	0.02	-0.16	0.04	0.02	0.16	0.06
Government expansion	-0.04	-0.09	0.06	0.04	0.10	0.06
Labour market	0.04	-0.27	0.07	0.04	0.27	0.09
Exchange Rate	-0.06	-0.10	0.04	0.06	0.10	0.04
Exogenous shocks						
Monetary Policy	0.01	0.01	0.00	0.01	0.01	0.01
Supply chain	-0.04	0.07	0.06	0.04	0.09	0.06
Energy price	0.06	-0.07	-0.05	0.06	0.07	0.08

Moving on to recent inflationary development, Table 2 shows the yearly sum of deviation in inflation and the contribution of each shock under "Normal values". The same information is contained under "Absolute values" but in absolute values, meaning that it takes into account all deviations from the steady-state and not only the sum of deviations during each year. As displayed in Table 2, 2020 started a new volatile period where structural labour market shifts and the output gap have been the main contributor to movements in inflation. Historically more modest contributors such as Government Spending, Energy prices and Supply chain shocks have been more prevalent during this period. The supply chain shocks are notable as they barely contributed in earlier years, whilst they have since 2020. Interestingly enough, it is the only driver that contributed positively to inflation (except for foreign monetary policy, but its effect was negligible), while all others drove it down.

Moreover, during 2020, the less temporary shocks (the output gap shock and the labour market shock) contributing the most to changes in inflation imply that recent inflationary behaviour is not only transitory. That is, in recent times, the drivers of inflation for both the negative and positive deviations from steady-state have mainly been shocks that are less transitory. Furthermore, the output gap shock and the labour market shock contributed more during the disinflationary period of 2020 than in the inflationary period of 2021, implying that the recent surge has been less driven by these two shocks. This makes sense since the variables whom these shocks came from had a much greater deviation during the dip than during recent surges. The labour market shock having less contribution to the recent surge in inflation can be seen as there not having been the same type of events and developments in the labour market in Sweden as in the US. Our result suggesting that Sweden is not experiencing a "Great resignation" is in line with comments made by the president of the European central bank, Christine Lagarde, suggesting that Europe is not experiencing a "Great resignation" (Horowítz, 2022). The inflationary pressure from the labour market in Sweden in 2021 may only be the labour market rebounding from the pandemic rather than a structural shift in the wage market.

The decrease in inflation that the increased slack (decrease in the labour market measure, which is a negative labour market shock) caused during 2020 is most likely due to two key factors. Firstly, for people still employed, less wage-bargaining power stemming from the many layoffs and from temporarily stopped union negotiations may have decreased inflationary pressure Rijswijk & Granath (2020). Secondly, people who lost their job were in a relatively worse wage-bargaining position due to many others also getting unemployed during a small time frame and due to uncertainty about the length of the pandemic.

Energy prices contributing little to inflation in the last quarter of 2021 (See Figure 11) reinforces some earlier findings from Sveriges Riksbank (2022c). That is, earlier studies have found that although energy prices have risen, the weight that energy prices have had in the consumer basket has not changed. Furthermore, they found that the indirect effect stemming from increased production costs could not be found in recent times. These two effects imply that changes in energy prices would have negligible effects on prices, a result we found in the last quarter of 2021. Furthermore, Bjellerup & Löf (2008) found that the indirect effect was much more sluggish, and it is plausible that these indirect effects have not yet come into play as of the fourth quarter of 2021. Another interesting result is that the absolute value for energy price contribution in 2021 differs from normal values, implying that energy prices have both driven inflation up and down.

Supply chain disruptions have had a prominent effect in driving up prices during the pandemic and the preceding period, in contrast to the pre-pandemic era, where disruptions took a more muted role. This result implies that inflationary pressure due to supply chain disruptions is a more recent phenomenon.

Government spending causing disinflationary pressure during 2020 could be due to the effect of the ZLB (discussed in Section 3.3) lowering the fiscal multiplier. Moreover, the low fiscal multiplier could have been further lowered by the restrictions and uncertain future prospects during the pandemic (Jørgensen & Ravn, 2022). Moreover, the short-term work scheme implemented during the pandemic has significantly lowered labour costs, implying a lower marginal cost (Swedish Ministry of Finance, 2022). Furthermore, firms have received other financial support during the pandemic (Swedish Ministry of Finance, 2021a). The financial support and the work schemes may have lowered marginal costs, making firms able to lower their prices. Hence, the result that government spending during the pandemic showed disinflationary behaviour makes sense.

Furthermore, Government spending has seen a greater contribution to inflation in the fourth quarter of 2021, implying the large expansions made in the face of the pandemic may have caused inflationary pressure (Swedish Ministry of Finance, 2021a).

The channels suggested in Section 3.3, seem to have contributed reasonably to inflation movements, especially when analysing 2019 to 2021. Supply chain disruptions positively contributed to inflationary behaviour during and after the pandemic. Energy price and supply chain disruption shocks have been less prevalent historically, meaning that when analysing longer horizons (outside of the pandemic), one may want to change these two factors.

6.3 Forecasted Determinants

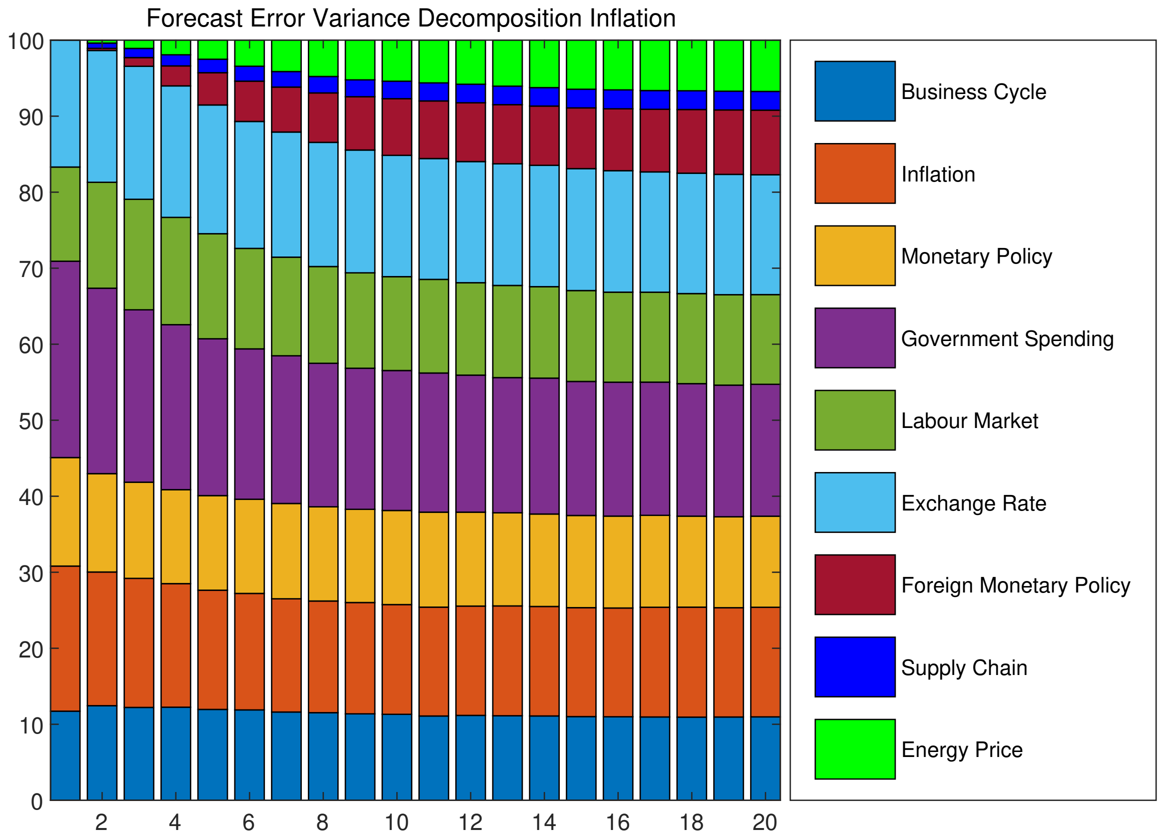

Figure 12: FEVD of Inflation of the Main Estimation

Figure 12 shows the forecasted contributors to movement in inflation for the period 2022 to 2026 (20 quarters ahead) based on the estimated VAR and the sample data. The Output gap, the Domestic Monetary Policy, Government Spending, Labour market, Exchange rate shocks and the shock stemming from inflation itself are all forecasted to affect inflation evenly, with Government Spending being the biggest. Energy prices and Foreign monetary policy shocks are estimated to increase their contribution successively over time. The trend is similar for the supply chain shock, although it will continue to have a modest effect.

The FEVD suggest that government spending will be the largest contributor to inflation volatility in the future, meaning that the sluggish effects of government spending on inflation are forecast to have set in as of the fourth quarter of 2021 and are estimated to have a persistent contribution to future movements.

The forecasted greater contribution of foreign interest rates to future inflation movement implies that foreign monetary shock will have a greater impact on inflation than it has had since the start of the ZLB. The greater contribution may also be due to agents, for the first time in a long time, seeing the rate increase, causing changes in future expected rates.

The FEVD in Figure 12 suggests that future volatility will be more affected by energy price shocks than what has been seen up to the fourth quarter of 2021, which is in line with the higher energy prices seen at the beginning of 2022. The increased contribution of energy price shocks will most likely increase even more from the decrease in imported Russian energy imposed by sanctions.

Consideration on where to focus policy measures to battle inflation should be done based on the information given above, which the following section discusses. Furthermore, the section also includes a discussion on whether measures taken during the pandemic have empirical support.

6.4 Policy Implications

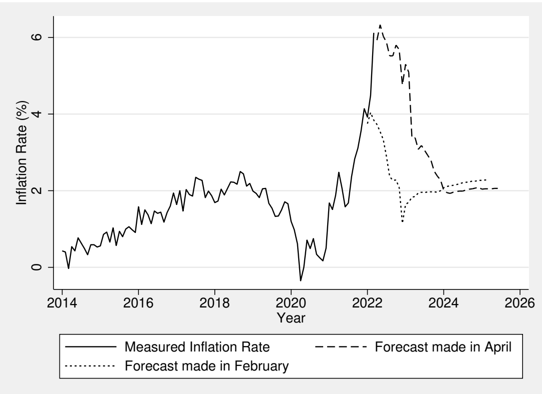

Figure 13: Inflation Forecasts made by Riksbanken

Note: Solid line refers to outcome, broken lines represents the forecasts.
Source: Sveriges Riksbank (2022b)

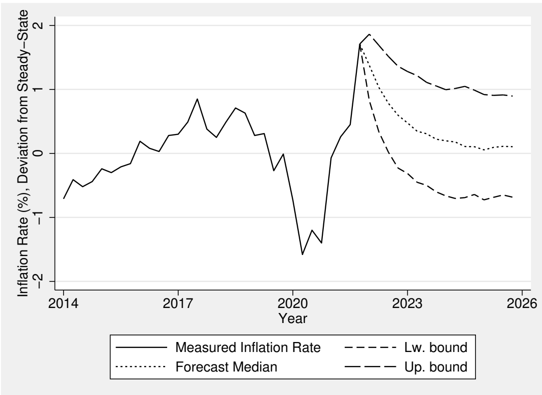

Figure 14: Inflation Forecasts made by Authors

Note: Solid line refers to outcome, broken lines represents the forecasts.
Source: authors calculations

Figure 13 shows the forecast of inflation from Sveriges Riksbank (2022b) from their latest published Monetary Report from April 2022. In the report, they are concerned about the high rates persisting and causing high inflation expectations. The Riksbank motivate the rise in the repo rate by this concern, and they estimate that they will gradually increase it up to 2% in 2026. Nonetheless, they give most of the credit for recent inflation to higher energy prices and supply chain disruptions created by imbalances in supply and demand. Furthermore, they suggest that the recent surge is transitory and that, in combination with a higher policy rate, the inflation rate will move back to the target of 2% in 2024.

The forecast computed by us is displayed in Figure 14 and agrees fairly well with the forecast from Riksbanken.[3] Our estimates argue significant contribution of labour market shift to inflation deviations, an effect the Sveriges Riksbank (2022b) seems to neglect. The Riksbank suggests that wage pressure from the labour market shift has only contributed very modestly to inflation but warns of future higher contributions if they become consolidated in inflation expectations. While reports suggest high contributions to inflation in the US from dramatic labour market shifts (the Great Resignation), the same could not be argued in Sweden, at least when taking the Riksbank's report and our results into account. This is likely due to a much more flexible labour market in the US with higher volatility in unemployment and weaker negation power.

Moreover, our result that future inflation movement would be more affected by energy prices and supply chain disruptions are in line with the Riksbanken report. We argue, through the findings of 2008, that although the indirect effects of energy prices have not yet set in, they may do in the future. Riksbanken is aware of this but argues that the energy price hikes are still mostly transitory.

Nonetheless, it should be highly noted that this study's estimations did not include data for the first quarter of 2022, where a lot of alarming inflationary developments have occurred; for example, the Russian invasion had not even begun until February 2022. This study's forecast has therefore been unable to capture all the increased uncertainties that occurred recently. Our forecast, similar to Sveriges Riksbank (2022b), suggest that energy prices and supply chain disruptions are mostly transitory. They continue to explain that a highly uncertain economic environment has emerged, which may cause more persistent inflation in the future.

[3] the lower and the upper bound of our forecast represent a 68% interval

7 Robustness Tests

The following section discusses two alternative specifications to better understand and test the robustness of the results in the main estimation.

7.1 Main vs Parsimonious model

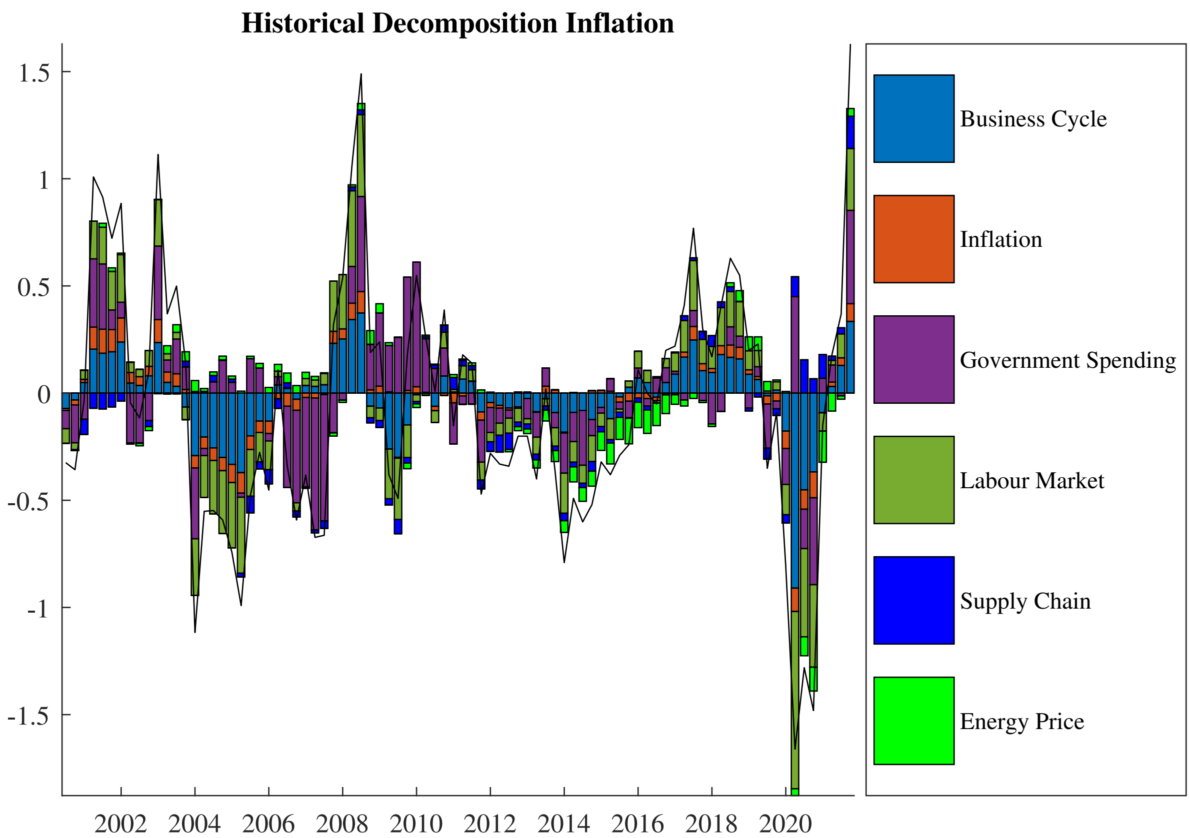

Figure 15: HD from the Parsimonious model of CPIF Inflation, year-on-year changes in deviation from the steady-state.

The extended model results may be hard to interpret due to the large number of channels included in it. We, therefore, chose to include a model that includes fewer variables and is generally more parsimonious.[4] We chose to include inflation, for obvious reasons, the output gap due to it being the most fundamental variable for the NKPC and the four suggested channels, Government spending, labour market slack, supply chain pressure and energy prices. The SZR are identical to the extended model but with three of the

[4] Generally, the model with the best fit and the least amount of variables is preferred, i.e. the most parsimonious model. For us, having the parsimonious model is important, but it is not the complete story. The estimation done above can be seen as the most parsimonious model due to it having the highest adjusted R^2 (.418). Even though the model with fewer variables is generally assumed to be parsimonious, adding more channels allows us to not falsely give a contribution to a channel.

variables excluded.

The HD in Figure 15 for the Parsimonious variable selection model suggests a similar relationship as the extended one, strengthening the robustness of the results of the Main Estimation. There are, however, some slight differences, with government spending now taking a more prevalent role. All variables are estimated to contribute more, with the largest increase in contribution to government spending. The more prevalent role of government spending may have to do with fiscal multipliers, which are related to interest rates. That is, an increase in the fiscal multiplier that the parsimonious model suggests is sole due to government spending are actually due to shifts in interest rates. During the period around 2010, government spending greatly affected inflation movements, but, for the main estimation, the contribution is nowhere near as large. At this time, both foreign and domestic rates saw significant decreases (see Figure 21 and Figure 25), implying an increase in inflation and an increase in the fiscal multiplier. The parsimonious variable model does not include the rates; therefore, these effects could be transferred to the fiscal multiplier, making it overestimate the inflationary effects of government spending. Another implication of these results is that they reinforce the importance of adding foreign and domestic interest rates to correctly assess the contribution to movement by each channel. Moreover, the results for the magnitudes and the sign of the contributions of the four channels to inflation are generally the same for both of these regressions, implying that the relationship given by the extended model is to be trusted.

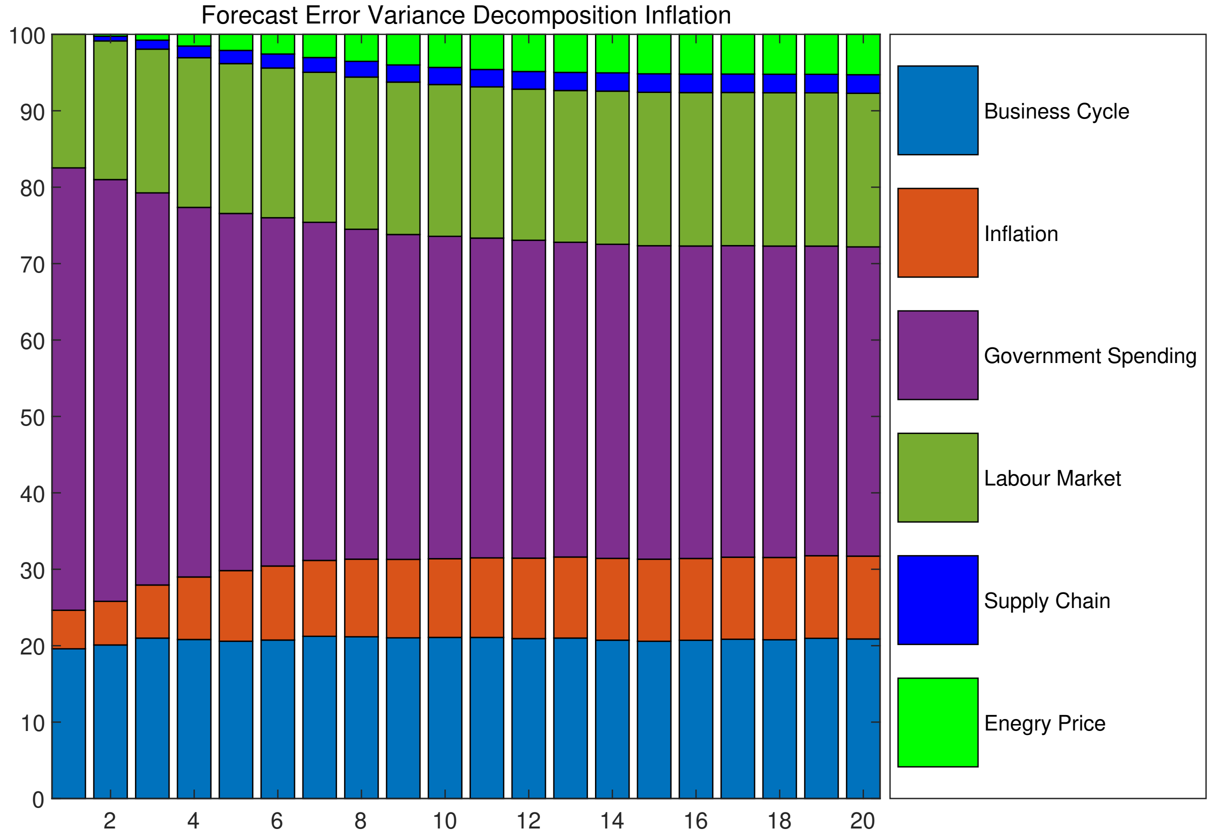

Figure 16: FEVD of Inflation of the main estimation

The FEVD in Figure 16 suggest similar development to the main estimation, but with larger shares given to each shock. Moreover, the high contribution of government spending seen in the HD can also be seen in the FEVD. Interestingly, government spending is assumed to have its highest contribution to inflation at the beginning of 2022 and is forecasted to contribute less as we reach 2026. The large spending that occurred during 2020 and 2021 is assumed to have a sluggish effect and should start to contribute more at the beginning of 2022. However, government spending should decrease in contribution as the surge in spending during the pandemic is not a recurring trend. If we take the overestimation of government spending due to no policy rates into account, then the results for the extended model are strengthened.

7.2 The effects of the Zero Lower Bound

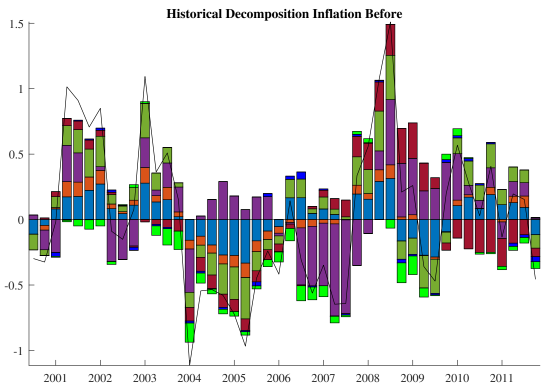

Figure 17: HD before ZLB

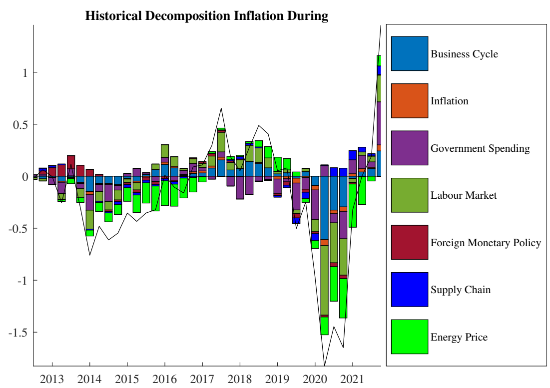

Figure 18: HD During ZLB

Furthermore, we want to analyse whether the inflationary dynamics have changed after the ZLB has started to bind. We, therefore, split the sample into two time periods. The first period spans from the first quarter of 2000 to the last quarter of 2011, and the second time period spans from the first quarter of 2012 to the last quarter of 2021. The choice of dividing the sample at this point was made as monetary policy in Sweden, and the Euro countries, faced the ZLB around this time (Altavilla, Burlon, Giannetti & Holton 2022). Moreover, we chose to estimate the parsimonious model with foreign policy rate. The choice of using the parsimonious model was made due to it better fitting the smaller sample size. For obvious reasons, we had to also include a policy rate in the estimation. The choice of including only one policy rate is the same as why we choose the parsimonious model, the smaller sample size. The estimation was conducted for both rates, but, as they yielded similar results, we chose to only display the rate that best illustrated the binding ZLB, the foreign policy rate. Furthermore, not including the domestic policy rate and the exchange rate allow us to more clearly distinguish and compare the other channels in the HD. The SZR are identical to the main estimation but without the two omitted variables.

The results for the regressions are displayed in Figure 17 and Figure 18. Firstly, we see a clear difference in the contribution of foreign monetary policy from Figures 17 to Figure 18. Interestingly enough, energy prices seem to have had an increase in importance after the ZLB, whilst the opposite can be said for government spending. For government spending, in contrast to traditional New Keynesian theory, the fiscal multiplier seems to have decreased. In fact, spending seems to sometimes have a deflationary effect (See from 2012 to 2015 in Figure 18, where government spending-to-GDP was high, but estimates imply it had a deflationary effect). The changed behaviour we found in our model is not in line with New Keynesian theory, but they are in line with other empirical findings of inflationary effects of government spending during the ZLB (Jørgensen & Ravn, 2022; Choi, Shin, & Yoo, 2022). Our results, therefore, reinforce these empirical findings. Moreover, earlier studies seem to have found an increase in the responsiveness of oil prices to economic activity (Datta et al., 2021). Increased responsiveness of oil prices (our measure of energy prices includes oil) explains the recent more prevalent role of energy prices to movement in inflation when the ZLB is binding.

The effects that the ZLB had on inflation dynamics were apparent. Going forward, it is important that economists and policymakers take these changed dynamics into account.

8 Conclusion

This study aims to analyse the drivers of recent inflation development and historical trends. Using a BSVAR model, we found that inflation in 2020 was mainly driven by the output gap and labour market activity, whilst 2021 has seen a greater contribution to inflation by more transitory shocks such as energy prices and supply chain shocks. Moreover, the future is estimated to be more affected by energy prices and foreign monetary policy shocks than can be seen up to the fourth quarter of 2021. The results are similar using a more parsimonious model, only with a greater contribution to the government spending shock. Furthermore, a clear shift in the HD can be seen between a binding and a non-binding, ZLB with foreign monetary policy shocks almost diminishing, government spending shocks becoming partly deflationary, and energy prices being more prevalent.

The results show that the NKPC still have relevance and is still helpful in explaining inflationary behaviour. However, one can not always rely on it alone, and policymakers must always be alert to what happens in the world, which in one way or another may affect the economic system. Unpredictable and uncontrollable events may happen that affect inflation, and if policymaker misinterprets their origins, there is a risk of severely causing even more harm to the economy and inefficient allocation of resources.

When policymakers try to battle future inflation, it is important to consider the underlying drivers. Firstly, the contribution of energy price shocks is highly dependent on the length at which these prices remain high. If energy prices are high for too long, then the higher marginal cost of production would be pushed on to consumers, and the inflationary effects would be more persistent. The same reasoning goes for supply chain disruptions.

When policymakers act on these disturbances, they should consider the change in persistence that these shocks will have given their length.

The results given by our study must be taken with some caution as it suffers from some limitations. Firstly, it is unclear whether the effect of inflation expectations could be captured within our BSVAR as we did not include any direct measure for it. Secondly, it is impossible to take every channel that affects inflation into account; therefore, there may be some channel missing from the BSVAR that would alter the dynamics slightly. Thirdly, inflation is notoriously hard to forecast, and unexpected events occurring after the fourth quarter of 2021 have not been considered. Therefore, the FEVD may be misleading. Fourthly, our suggested proxies for each of the shocks we measured may not capture the complete story and implementing other SZRs may alter the results.

Future research should focus on the relationships between the drivers and policies implemented in the face of the pandemic. More specifically, researchers should analyse the link between the Short-term work scheme and the effect of labour market slack on inflation during the pandemic. Furthermore, there is a need to analyse if the channels are more or less prevalent in different countries and why this may be the case. It may be interesting to analyse differences in the flexibility of a country's labour market and how it corresponds to whether that country experienced the Great resignation or not.

Moreover, research should focus on extending our analysis by using updated data for the model variables. By doing this, more information regarding how the four channels affect inflation after the pandemic will be given. Furthermore, researchers should be considering new channels as the economic climate changes. After the sample data used in this thesis has ended, even more events that raise concern for continued inflation have occurred. For example, the Russian invasion of Ukraine, which may cause higher continued higher energy prices and also increased food prices, as well as new lockdowns in China causing more harm to the supply chain, should all be taken into consideration (Sveriges Riksbank, 2022b).

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Appendix A. Sources of Data

Table 3: Summary of variables, description and data sources

Variable	Description	Data Source
Inflation	Consumer price index with fixed interest rate, not seasonally adjusted, 1987 reference year	Statistics Sweden
Energy Price	Harmonized consumer price index, not seasonally adjusted, 2010 reference year	Eurostat
Monetary Policy	Short-term interest rate set by the Riksbank & 3-Month Rates and Yields: Interbank Rates for the Euro Area	Sveriges Riksbank, ECB
Exchange Rate	Krona index, the SEK's weighted exchange rate, corresponding to the size of the trade flows to Sweden's 32 biggest trading partners	Sveriges Riksbank
Supply Chain	Global Supply Chain Pressure Index	FED NY
Labour Market	Ratio of Employment to Population, seasonally adjusted	Eurostat, Statistics Sweden
Output Gap	Gross domestic product, expenditure approach, ppp adjusted, 2010 reference year, SEK, millions, seasonally adjusted	FRED St. Louis
Governmental spending	Final consumption expenditure of general government, SEK, millions seasonally adjusted	Eurostat

Go back to Data.

Appendix B. Bayesian estimation

.1 Theory

This section is dedicated to explaining the Bayesian procedure used to estimate the reduced-form VAR. Firstly, the parameters of interest are the ones contained in the reduced form matrices $(B_1, ..., B_p)$ and the variance-covariance matrix for the residuals Σ_n. We chose to estimate the reduced-form VAR parameters using Bayesian methods. The advantages of choosing Bayesian as opposed to frequentist methods are several. The most relevant advantage is the lower risk of overparameterization that the estimates are too dependent on the sample and may not represent the population as a whole.

Before we continue, following Dieppe, Legrand, & Van Roye (2016), we rewrite the reduced form model (4) into a more compact form to ease computation.

Firstly, the matrices are added into a compact form:

$$\begin{pmatrix} y_1' \\ \vdots \\ y_T' \end{pmatrix} = \begin{pmatrix} y_0' & \cdots & y_{1-p}' & c_1' \\ \vdots & \ddots & \vdots & \vdots \\ y_{T-1}' & \cdots & y_{T-p}' & c_T' \end{pmatrix} \begin{pmatrix} B_1' \\ \vdots \\ B_p' \\ I_n \end{pmatrix} + \begin{pmatrix} \epsilon_1' \\ \vdots \\ \epsilon_T' \end{pmatrix} \tag{B.1}$$

with:

$$Y = \begin{pmatrix} y_1' \\ \vdots \\ y_T' \end{pmatrix} \qquad X = \begin{pmatrix} y_0' & \cdots & y_{1-p}' & c_1' \\ \vdots & \ddots & \vdots & \vdots \\ y_{T-1}' & \cdots & y_{T-p}' & c_T' \end{pmatrix} \qquad B = \begin{pmatrix} B_1' \\ \vdots \\ B_p' \\ I_n \end{pmatrix} \qquad \epsilon = \begin{pmatrix} \epsilon_1' \\ \vdots \\ \epsilon_T' \end{pmatrix} \tag{B.2}$$

Also written as:

$$Y = XB + \epsilon \tag{B.3}$$

The expression in (B.3) can be compressed even further, using vectorization, yields (B.4).

$$y = \bar{X}\beta + \varepsilon \tag{B.4}$$

with:

$$y = vec(Y) \qquad \bar{X} = I_n * X \qquad \beta = vec(B) \qquad \varepsilon = vec(\epsilon) \tag{B.5}$$

The final expression (B.4) with y, $\bar{X}$, β and ε contains the sample data at time t, the sample data for the lagged periods p, the model parameters and the residuals.

For the Bayesian approach, the parameters are assumed to be random draws from some distribution and the variables are assumed to be fixed values (as opposed to frequentists where the parameters are fixed and the variables are random). Given the distributional information of the parameters, point estimates can be computed, which are the estimated parameter values put into the VAR. Point estimates are often the mean or the median, depending on the approach. The median is often preferred over the mean as the median is less affected by outliers, and it makes sure that the point estimate is within the credibility interval. For our chosen approach, the point estimate is the median.

The objective of the Bayesian estimation is to find the probability density function $P(\beta|y)$ for the unknown parameters given the data we put into the VAR, formally known as the posterior. The posterior can be obtained using Bayes theorem, where it is equal to the likelihood function $f(y|\beta)$ times the prior $P(\beta)$, divided by the data density $f(y)$. The likelihood function is the likelihood that data was observed given the parameters, and the prior is the probability density function for the parameters not taking the sample data into account. The data density is independent of the parameters and is often ignored in the final expression for the posterior (6).

$$P(\beta|y) \propto f(y|\beta)P(\beta) \tag{6}$$

Using the posterior as opposed to strictly using the likelihood (which would be done using the frequentist approach) implies identifying the correct maximum of the likelihood. That is, if we were to only use the likelihood function, we would be brought to the closes maximum point, which may not necessarily the be the global one. Using a prior distribution allows us to guide the likelihood function to the correct hill, making it climb the global (as opposed to a local) maximum. Note that β is a vector of parameters; therefore, the prior (and ,in turn, the posterior) is a joint density function for all of the parameters (See equation (7)).

$$P(\beta) = P(A_1^{(1)}) \times P(A_2^{(1)}) \times \cdots \times P(A_p^{(n)}) \tag{7}$$

.2 Minnesota priors

To correctly identify the posterior distribution, we use the Litterman (1986) approach of Minnesota priors. The Minnesota prior approach goes as follows; The multivariate prior distribution has a mean of 1 for a parameter's first own lag (0.8 for stationary series) and a mean of 0 for all lags greater than one and for all cross parameters. As our data series are stationary, we choose a mean of 0.8 for the first lags.

$$P(\beta) \sim \mathcal{N}(\beta_0, \Omega_0) \tag{8}$$

with:

$$\beta_0 = \begin{pmatrix} 0.8 & 0 & \ldots & 0 \end{pmatrix}' \tag{9}$$

The variance-covariance matrix of the prior distribution consists of so-called hyper-parameters. Hyper-parameters represent the relationships between the variances of the variables in the VAR model. λ_1 is an overall tightness parameter, λ_2 is a cross-variable specific parameter, λ_3 is a scaling coefficient representing the speed at which parameters for lags greater than one converges to zero, and λ_4 is a parameter regarding the relationship between constant or exogenous variables and other endogenous variables (our model will not include any exogenous variables, except for the ones present in the exogeneity block; therefore, this parameter only represent the relationship to the constant in the VAR). Our choices for hyper-parameters follow the literature and are not controversial.

Following other scholars such as Corbo & Di Casola (2022), we set the tightness parameter λ_1 to 0.2, the cross-variable parameter λ_2 to 0.5, the lag decay parameter λ_3 to 1 and the parameter regarding constants and exogenous variables to λ_4 to 1. These choices are made due to Sweden being a SOE, and consensus regarding using these values for SOEs exists. Given these hyper-parameters and autoregressive variances for the model variables estimated using Ordinary Least Square (OLS), we can compute the variance-covariance matrix for the multivariate prior distribution.

When we have a specified distribution for the prior, only a well-defined likelihood function is needed to properly identify the posterior. The Likelihood function (10) follows standard procedure and is expressed as the function for multivariate normal distribution.

$$f(y|\beta, \bar{\Sigma}) \propto exp \left[-\frac{1}{2}(y - \bar{X}\beta)'\bar{\Sigma}^{-1}(y - \bar{X}\beta) \right] \tag{10}$$

The variance-covariance matrix $\bar{\Sigma}$ is estimated using OLS for the reduced-form VAR (4).

Go back to Structural Vector Autoregression.

Appendix C. Impulse Response Functions for the Main Estimation

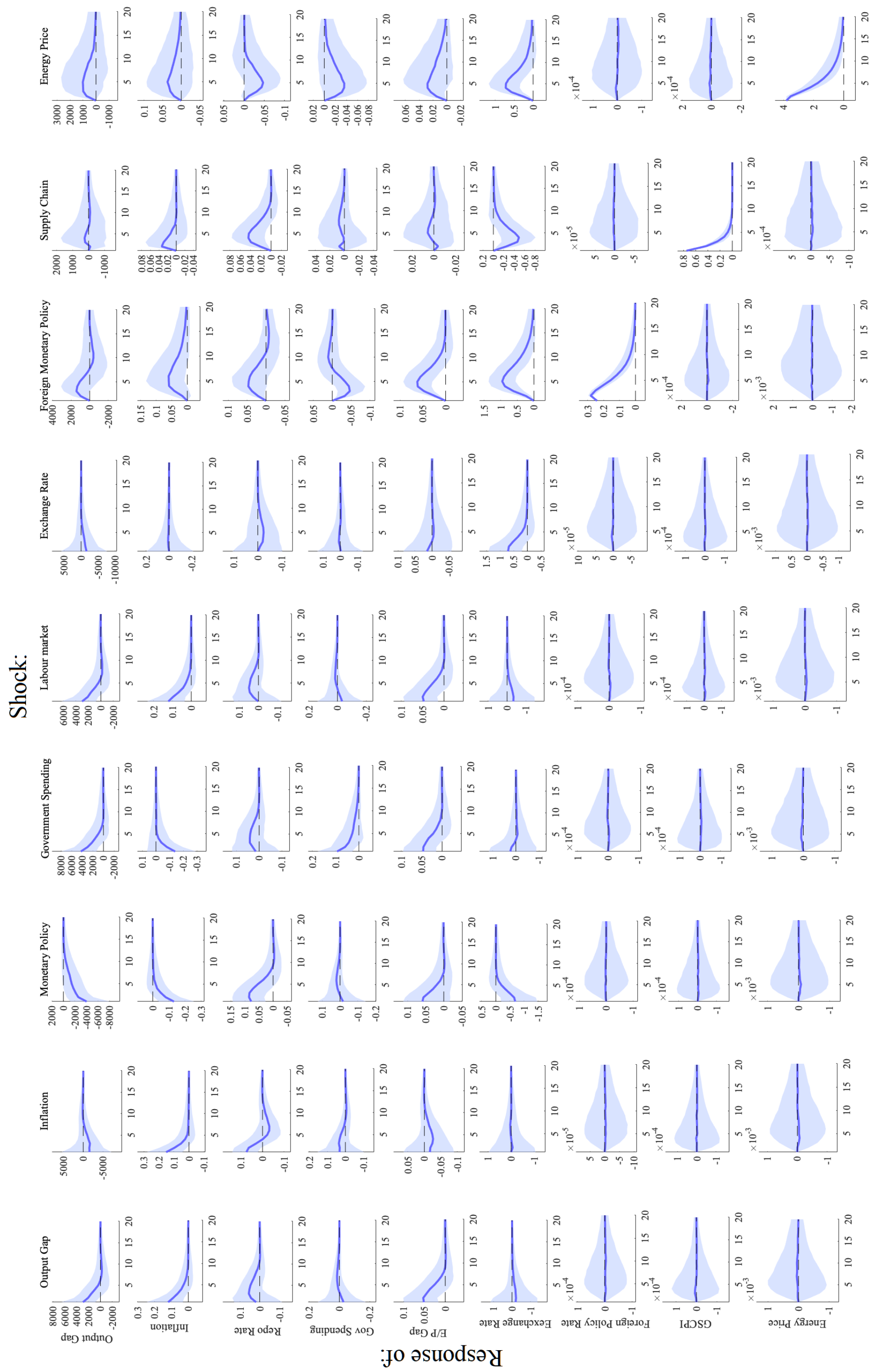

Figure 18: Impulse Response Functions

Go back to Result.

Appendix D. Overview of Variables

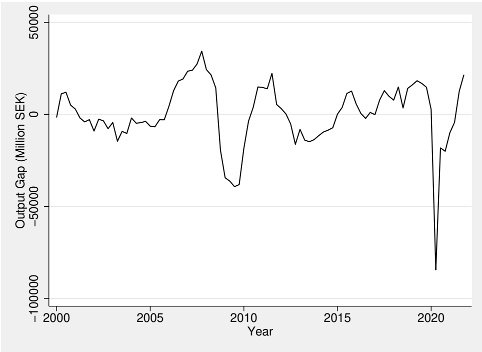

Figure 19: Output Gap

Source: FRED St. Louis, authors calculations

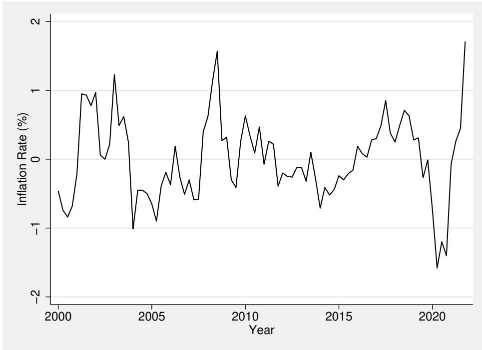

Figure 20: Inflation Rate Annual Change, Detrended

Source: Statistics Sweden, authors calculations

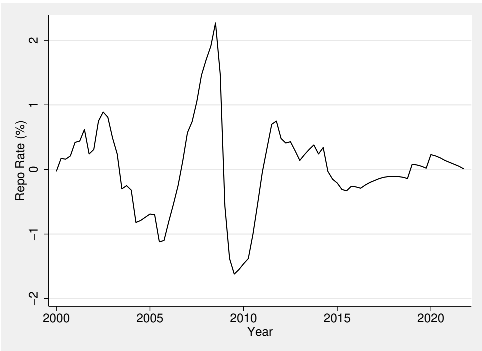

Figure 21: Domestic Monetary Policy, Detrended

Source: Sveriges Riksbank, authors calculations

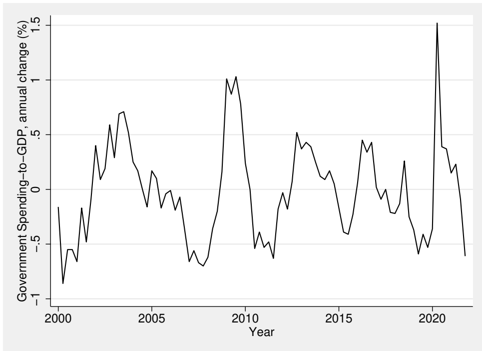

Figure 22: Government Spending, Detrended

Source: Eurostat, authors calculations

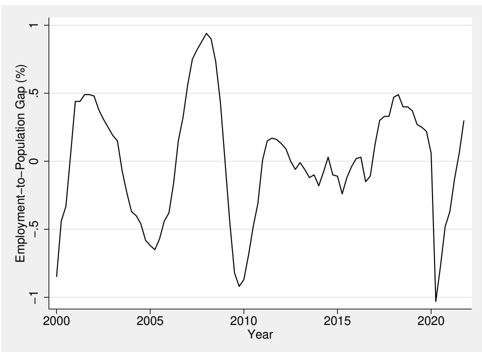

Figure 23: Labour Market, Detrended

Source: Eurostat, Statistics Sweden, authors calculations

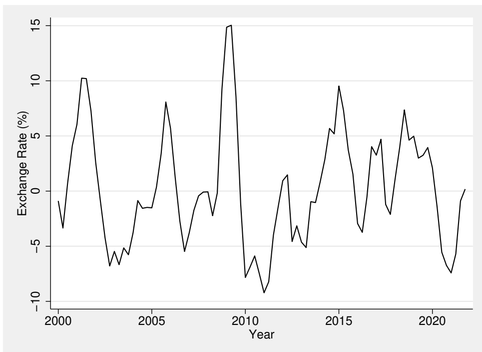

Figure 24: Exchange rate, Annual Change

Source: Sveriges Riksbank, authors calculations

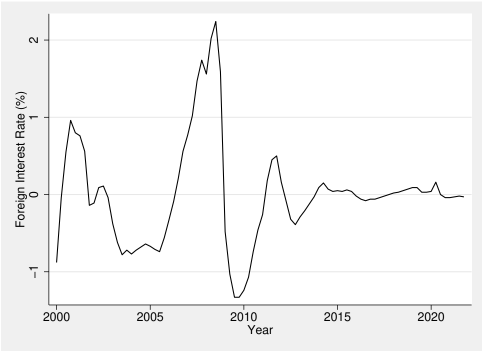

Figure 25: Foreign Monetary Policy, Detrended

Source: FRED St. Louis, authors calculations

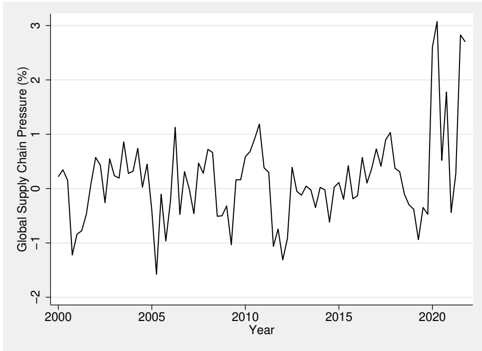

Figure 26: Supply Chain, Annual Change

Source: FED New York, authors calculations

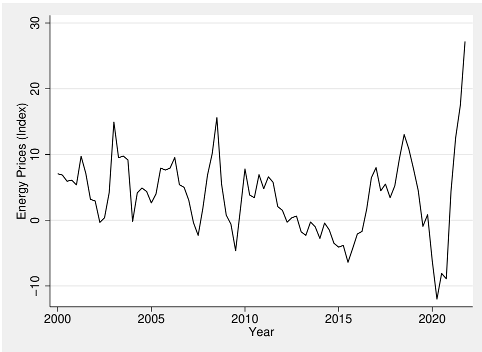

Figure 27: Energy Prices

Source: Eurostat

Go back to Data.