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How does the Weakened Swedish Krona Impact the Inflation?

A Bayesian VAR Analysis of Exchange Rate Pass-Through

by

Ebba Wallin

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Supervisor: Marta Giagheddu

Lund University School of Economics and Management

Department of Economics

Abstract

Exchange rate pass-through to prices differ depending on the underlying shock. Furthermore, the mechanisms causing inflation behave diversely, conditional on why the exchange rate fluctuates. This paper investigates how prices react relative to the exchange rate movements, i.e., the exchange rate pass-through, following specific shocks, how the frequency of price adjustment is affected by shocks, and, consecutively, how the frequency affects the price level. The study uses a Bayesian vector autoregression approach with Swedish data from 1995 to 2022. Zero and sign restrictions are imposed, and six shocks are identified, of which two are global. The paper finds that the pass-through to consumer prices is the most significant succeeding monetary policy and exchange rate shocks. Post the Covid-19 pandemic, there has been a shift in the decomposition of consumer price inflation, with global shocks driving a larger share of the variation. Variations in the frequency of price adjustment are primarily driven by global shocks. Moreover, the frequency of price adjustment's pass-through to consumer prices is volatile.

Keywords: Exchange rate pass-through, Consumer price inflation, Frequency of price adjustment, Import price inflation, Bayesian vector autoregression

Contents

List of Figures

List of Tables

1 Introduction

Exchange rate movements vary over time. Fluctuating exchange rates create pass-through to import and consumer prices. The degree to which exchange rate movements affect prices is called the exchange rate pass-through (ERPT). Currency movements impact the overall economy and influence policymakers' determination of monetary policy (Forbes, Hjortsoe & Nenova, 2015). The impact of the exchange rate fluctuation on the economy depends on its underlying cause. For instance, firms are expected to decrease prices if an exchange rate appreciates following a restrictive monetary policy leading to decreased demand. On the contrary, a price increase is anticipated if the appreciation is acquired from a positive demand shock (Forbes, Hjortsoe & Nenova, 2015). The diverse responses highlight the relevance of studying the relationship between prices and exchange rates, conditioned on the underlying shock.

Sweden is an interesting country to study when assessing the role of pass-through to prices. To begin with, Sweden is a small open economy with a significant dependence on trade and foreign relations. The Swedish Central Bank practices inflation targeting, its primary objective since implementing the inflation target in 1995. Accordingly, Sweden displays several characteristics typical for a small, advanced open economy. Furthermore, Sweden faces the highest inflation rate in over 30 years, and in January 2023, the Swedish currency was the weakest since 2009 (Ohlin, 2023; Statistics Sweden, 2023). Based on this, the media has debated whether Sweden's weakened currency, the Swedish Krona, has contributed to the rising inflation as the cost of imported goods rise when the domestic currency depreciates (see Frenker, 2022; Pihl, 2023; Westman, 2022).

An extensive field of research focuses on the linkage of prices and exchange rate movements (see for example, Dornbusch, 1987; Khan & Savoie-Chabot, 2015). However, most published work incorporates a "rule of thumb" approach, applying historical relationships to understand current exchange rate and price developments (Forbes, Hjortsoe & Nenova, 2015). In contrast, a few recent studies have incorporated the components causing exchange rate fluctuations when investigating the ERPT to prices. This approach was first utilized by Shambaugh (2008), who used a structural VAR model to examine the role of the underlying shock which makes the exchange rate fluctuate. Shambaugh's

methodology was later developed and utilized by Forbes, Hjortsoe, and Nenova (2015) and Corbo and Di Casola (2018), who investigated the ERPT to prices in Sweden from 1995 to 2017.

This paper aims to examine the pass-through from exchange rate movements to prices in Sweden following a shock causing exchange rate fluctuations. Further, the role of the frequency of price adjustment on consumer price inflation is investigated. The thesis examines Sweden from the second quarter in 1995 to the last quarter in 2022. Accordingly, the paper covers events such as the Global Financial Crisis, the period of the negative policy rate, the Covid-19 pandemic, and Russia's invasion of Ukraine. From what I know, the ERPT in Sweden following the latter two events has not been studied previously. As the Swedish economy hitherto has been particularly vulnerable to disruption to global supply chains, the recent episodes are particularly interesting (Corbo & Di Casola, 2018). Furthermore, the analysis considers a channel not, to my knowledge, investigated previously for the Swedish economy: the role of the frequency of price adjustment on price inflation. The frequency of price adjustment has increased in the last decade in Sweden, making its relationship with exchange rate movements and inflation rate relevant to investigate (Ewertzh, Klein & Tysklind, 2022; Nakamura & Zerom, 2010). My paper contributes to the current research literature by examining the impact of these recent global events and by studying a novel channel for ERPT: the frequency of price adjustment. This paper builds on the approach proposed by Shambaugh (2008). The study begins by replicating Corbo and Di Casola's (2018) work over a more extended period. Swedish data from the second quarter of 1995 to the last quarter of 2022 is used, which is five additional years to what Corbo and Di Casola (2018) include.

Several publications are focusing on ERPT in small open economies. Some examples are Faruqee (2006), McCarthy (2007), and Ortega and Osbat (2020). However, only a few studies focus on the role of the underlying shock driving exchange rate movements in small open economies (Corbo & Di Casola, 2018). Known studies on this specific topic are Shambaugh (2008), who studied the ERPT in 16 countries with different characteristics, Forbes, Hjortsoe, and Nenova (2015), who studied the ERPT in the UK, and Corbo and Di Casola (2018; 2022), who investigated the ERPT in two small open economies: Sweden and Canada.

Structural VAR models are estimated with a Bayesian technique. The paper identifies four domestic and two global shocks and imposes sign and zero restrictions. The models are estimated using six macroeconomic variables. The object of focus is the relationship between exchange rate fluctuations and consumer prices concerning the specific shock driving the movement. Three structural VAR models with different specifications are estimated: one explaining the evolution of consumer prices, one where import prices are incorporated to study how exchange rate fluctuations affect those and are later transmitted to consumer prices, and one final where the impact of exchange rate movements on the frequency of price adjustment is examined. Besides the four domestic shocks, the first specification includes foreign prices and quantities, which enables the assessment of the role of both global supply and demand shocks on ERPT to consumer prices. The inclusion of import prices in the second specification makes it possible to examine how exchange rate fluctuations affect import prices and how these fluctuations are transmitted to consumer prices. Lastly, the final specification allows for appraising if the frequency of price adjustment reacts to exchange rate movements and if the frequency creates ERPT to consumer prices.

My empirical results confirm previous findings suggesting that the ERPT varies depending on the underlying shock driving the exchange rate movements. ERPT to consumer prices is the most significant following shocks to the policy rate (monetary policy shocks) and exchange rate shocks. Moreover, global shocks have created more ERPT to consumer prices since the global pandemic and Russia's invasion of Ukraine. Further, the recent exchange rate fluctuations have been an essential driver of the increasing Swedish consumer prices. Import prices are the most sensitive to monetary policy shocks. The frequency of price adjustment is notably affected by global and exchange rate shocks, and the ERPT from the channel to consumer prices is volatile.

The rest of the paper is organized as follows. Section 2 presents the previous literature and theoretical background, while Section 3 explores recent trends and developments in Sweden. Section 4 describes the methodology. The data is reported in Section 5, followed by Section 6, describing the estimation technique. Finally, Section 7 presents and discusses the results, while Section 8 concludes.

2 Previous literature and Theoretical background

When a currency depreciates, there are some direct effects on the consumer prices associated with the depreciation. The direct effects work through two main channels. When the domestic currency depreciates, imported goods become more expensive (Khan & Savoie-Chabot, 2015). It is also plausible that the increasing import prices following a depreciation increase the price of domestic goods. The increasing price of imported intermediate inputs raises the production cost of domestic goods, which can be passed on to the consumer (Ortega & Osbat, 2020). The exchange rate movements' impact on prices is captured in the concept called exchange rate pass-through (ERPT).

The ERPT's magnitude to consumer prices depends on several country-specific factors. To begin with, countries with low inflation, a credible central bank practicing inflation targeting, and a stable exchange rate tend to have low pass-through (Ha, Stocker & Yilmazkuday, 2020). Also, the price level is more sensitive to depreciation than appreciation (López-Villavicencio & Mignon, 2013). Secondly, if depreciation is expected to remain, producers are more likely to pass on the increased price of intermediate goods to their consumers to avoid falling profit markups (Khan & Savoie-Chabot, 2015; McCarthy, 2007). Whether the producer changes the prices charged to consumers also depends on the cost of switching prices. Lastly, the magnitude of the ERPT to consumer prices is affected by the composition of goods versus services and the share of imports in the consumption basket (Khan & Savoie-Chabot, 2015). For example, rising import prices might be offset by falling consumer prices for services or a diminishing share of imports in the consumption basket (Dellmo, 1996).

The exchange rate can also affect consumer prices indirectly through its impact on aggregate demand. When the domestic currency depreciates, domestic product demand rises both domestically and abroad as the goods become relatively cheaper. The increasing demand for domestic goods will eventually raise the demand for labor, putting upward pressure on wages. Higher wages can, in turn, increase the inflation of consumption goods (Khan & Savoie-Chabot, 2015). Another indirect channel is the exchange rate movements' effect on marginal costs. A fluctuating currency can affect foreign wages and global commodity prices, impacting production costs and pricing (Burstein & Gopinath,

2014).

Previous research has mainly focused on the role of structural characteristics when examining ERPT. The structural characteristics receiving the more significant part of attention in research are trade openness, the role of currency of invoicing, integration in global value chains, and the exporter's market power (see Forbes, Hjortsoe & Nenova, 2017; Gopinath, 2015; Ortega, Osbat & Rubene, 2020; Ortega & Osbat, 2020). Trade openness, in terms of openness to imports, affects the ERPT. When foreign products make up a larger share of the domestic market, fluctuations in the exchange rate are given a more considerable impact on inflation. The impact of trade openness on pass-through was investigated by Ortega, Osbat, and Rubene (2020). They found that less ERPT stems from goods with a lower share of imported components, as domestic content is incorporated in the product, than from products with a larger share of import content. Another aspect related to trade openness is increased competition. Ha, Stocker, and Yilmazkuday (2020) investigated this aspect and found that more productive and competitive firms benefit as the competition rises. These more productive firms tend to have their inputs sourced internationally, which lowers the ERPT.

The usual approach when determining ERPT is to regress changes of prices on past and present changes in the exchange rate and other included variables (Forbes, Hjortsoe & Nenova, 2015). An example of this could look as follows:

$$\Delta p_{n,t} = \alpha_n + \sum_{j=0}^{T} \beta_{n,j} \Delta e_{n,t-j} + \gamma_n X_{n,t} + \epsilon_{n,t} \tag{1}$$

Which is the estimation technique proposed by Burstein and Gopinath (2014). In the equation, $\Delta p_{n,t}$ is the log difference of the price index in country n at time t. $\Delta e_{n,t-j}$ is the log change in the country's nominal exchange rate, and $X_{n,t}$ is the trade-weighted foreign export prices. The ERPT is captured by $\sum_{j=0}^{T} \beta_{n,j}$.

An alternative measure of ERPT is used by Shambaugh (2008), Forbes, Hjortsoe, and Nenova (2015), and Corbo and Di Casola (2018). These publications utilize the pass-through ratios: the reactions of the exchange rate and prices to a specific shock (see Equation 3).

2.1 Frequency of price adjustment

To what extent the ERPT reaches the consumers depends on the frequency of price adjustment. The frequency channel has a close relationship with consumer price inflation (Ewertzh, Klein & Tysklind, 2022). Wulfsberg (2009) found that variation, rather than the magnitude of price increases, explains all inflation rate movements. Gopinath and Itskhoki (2010) established that imported goods whose prices are changed more frequently have a pass-through that is twice as large as the pass-through of products whose prices are changed by a low frequency. Generally, goods with a high frequency of price adjustment have more inelastic markups. The frequency of wholesale price adjustment is closely related to commodity cost volatility. In times of high volatility of commodity prices, the prices facing consumers adjust more frequently (Nakamura & Zerom, 2010). When volatility is high, firms adjust their markups upward to avoid negative profits (Agrawal, Gaurav & Suveg, 2021). Thus, the frequency feasibly increases if the imports become more expensive due to, for example, a weak exchange rate. In addition, if competitors face similar production cost shocks, firms have fewer incentives to insulate the price fluctuation in their markups and have a higher tendency to pass on the increased costs to the consumers (Nakamura & Zerom, 2010). Further, the speed of adjustment to a changing exchange rate depends on price stickiness. If prices are sticky, lags in adjusting to the new exchange rate along the distribution chain may appear (Hahn, 2003).

2.2 ERPT decline along the pricing chain

The degree of ERPT to consumer prices is lower than the pass-through to the prices at the border (Bacchetta & van Wincoop, 2003). This decline is because, along the supply chain, the degree of pass-through naturally decreases as nontradeable components, such as rents, profits, and distribution costs, increase (Ito & Sato, 2008). Distribution costs add domestic content to the imported goods, for example, transportation and wholesale services. Thus, the share of the consumption goods directly linked to the imported goods decline while the local value added to the final good increase (Campa & Goldberg, 2006). A more considerable degree of ERPT from import to consumer prices is obtained when the extent of imported goods used in domestic production is high and distribution costs are low (Ito & Sato, 2008).

Ortega, Osbat, and Rubene (2020) studied how the ERPT in the Euro area is determined by integration in global value chains (GVCs). Their findings suggest that a country exporting to the Euro area while simultaneously sourcing some of its inputs from the same region will have a lower ERPT. Another aspect that has been studied actively is the role of the currency of invoicing. For countries whose imports are invoiced in a foreign currency, the pass-through will be more significant than if the imports were invoiced in the importer's currency, as exchange rate movements are reflected in the price. This channel has been studied by, for example, Devereux, Dong, and Tomlin (2017), Gopinath (2015), and Ortega, Osbat, and Rubene (2020), whom all find this relationship to hold.

2.3 Markups

Producers with more considerable market power tend to source more of their inputs globally, lowering the pass-through to consumer prices (Ha, Stocker & Yilmazkuday, 2020). In addition, the extent to which a producer can change its margins in response to changing exchange rates depends on its market and pricing power. Consequently, a greater concentration of producing firms decreases the pass-through as the producer's markups absorb some exchange rate fluctuations. Further, suppose distributors in the domestic market face intense competition. In that case, they will be willing to insulate exchange rate fluctuations in their margins, making the pass-through to consumer prices decline (Ortega & Osbat, 2020). However, there is a U-shaped relationship between the size of the exporter and the ERPT. Small and large exporters tend to have more pass-through than middle-sized exporters. This relationship is due to the little concern that very large or very small exporters have regarding what impact a price increase from their side will have on their share of the total market. Middle-sized exporters are more concerned by this and consequently have lower ERPT (Devereux, Dong & Tomlin, 2017).

2.4 Nature of shocks

Another possible source of varying degrees of pass-through is the role of shocks. The pass-through to inflation varies with the nature of the shock triggering the currency fluctuation (Forbes, Hjortsoe & Nenova, 2015; Shambaugh, 2008). This finding highlights the relevance of investigating the causes of exchange rate movements to understand the economy's reaction. One reason for varying pass-throughs depending on the shock's nature is

the price setter's reaction. It is plausible that price setting depends on why the currency fluctuates (Shambaugh, 2008). For example, suppose a weakened domestic currency appears due to monetary policy easing. In that case, import prices will rise alongside an increased aggregate demand, which puts upward pressure on the prices and a significant pass-through to consumer prices. On the contrary, if the depreciation is due to weak domestic demand, inflation may remain low, leading to a low ERPT. Thus, the price setting differs with the type of shock as different shocks affect marginal costs, competition, and demand differently (Forbes, Hjortsoe & Nenova, 2015). A few studies have investigated the impact of different types of shocks on the ERPT. Shambaugh (2008) investigated the pass-through in 11 economies and found that import and consumer prices react differently to shocks. Forbes, Hjortsoe, and Nenova (2017) studied how different types of shocks can explain various degrees of pass-through over time and found that monetary policy shocks create significantly more pass-through than demand shocks.

3 Trends in Sweden

As previously mentioned, Sweden has many properties that makes it interesting to study its ERPT. To begin with, Sweden is a small, very open to trade, advanced economy, and the Swedish Central Bank introduced an inflation target in early 1993, which has been followed since 1995. Secondly, the Swedish currency has been depreciating against the U.S. dollar and the euro for some time (Ohlin, 2023; Sveriges Riksbank, 2023). The Swedish Central Bank predicts that the depreciating currency and the volatile exchange rate will remain as long as there is uncertainty in the international financial markets (Sveriges Riksbank, 2022). This outlook increases the ERPT as producers are more likely to pass on the production costs to the consumers. Finally, Sweden faces the highest inflation rate in over 30 years, and inflation expectations are at the highest measured level (Konjunkturinstitutet, 2022; Statistics Sweden, 2023). Hence, it is relevant to understand the components driving the inflation rate.

3.1 Frequency of price adjustment in Sweden

In 2021 and 2022, the Swedish Central Bank conducted surveys among Swedish companies whose results suggest a faster pace in the rise of consumer prices. This price increase is mainly driven by exchange rate fluctuations, increased purchasing costs, and energy

costs (Sveriges Riksbank, 2022). However, the trend of increasing the frequency of price adjustments has been around for a while. Over the period 2010 to 2018, the price adjustments have been increasing in frequency while the size of the price change has remained constant. Thus, a higher frequency of price adjustment is a more significant determinant of inflation than the size of the price increase (Ewertzh, Klein & Tysklind, 2022). Sweden is at the top when comparing the price speed of adjustment across European countries (Bukeviciute, Dierx & Ilzkovitz, 2009). Moreover, the frequency of price adjustments correlates positively and significantly with the inflation rate, at approximately 0.8. The frequency of price adjustment is heterogenous across sectors and types of product groups, with food and energy having a higher frequency of price adjustment than other product groups (Ewertzh, Klein & Tysklind, 2022). Previous research has concluded that a higher frequency of price adjustment increases the ERPT (Gopinath & Itskhoki, 2010; Nakamura & Zerom, 2010). Therefore, the increased frequency of price adjustment may have contributed to a higher ERPT in Sweden.

3.2 Markups and declining ERPT along the pricing chain in Sweden

Sweden has a higher pass-through from producer to consumer prices than the average European country. In other countries, fluctuations are to a higher degree absorbed by decreasing markups (Bukeviciute, Dierx & Ilzkovitz, 2009). The higher pass-through implies that consumer prices are more sensitive to movements in producer prices in Sweden. Recently, signals indicate an increased willingness to pass on costs to consumers. For instance, between 2021 and 2022, the profit margins for food products increased (Konjunkturinstitutet, 2023). However, no trend suggests increased profit shares when looking at the overall profit share over a more extended period. Instead, the profit shares decreased slightly from 1995 to 2016 (Enegren & Jagrén, 2018). When comparing markups across EU countries, Sweden has relatively low markups. In the retail sector, the markups are non-existent, whereas the energy sector has the highest markup in Sweden (Canton & Thum-Thysen, 2015). Besides, the pass-through from increased costs of intermediate goods from producers to consumers is significant when the exchange rate is expected to depreciate (Khan & Savoie-Chabot, 2015; McCarthy, 2007). As the weak currency and the volatile exchange rate is expected to remain, the pass-through from producers to consumer prices is feasibly significant (Sveriges Riksbank, 2022).

3.3 The impact of shocks on the Swedish economy

Corbo and Di Casola (2018) found that Sweden is particularly vulnerable to global supply shocks. Their study established that global shocks explain the larger part of the variation in consumer price inflation, while domestic shocks affect exchange rate fluctuations to a greater extent. Moreover, since the Global Financial Crisis (GFC) in 2008, global shocks have had an increasing contribution to consumer prices. By assessing the nature of the shock causing the exchange rate to fluctuate, it is possible to determine how the ERPT changes, even over a short period. For example, Forbes, Hjortsoe, and Nenova (2015) utilized the nature of the shock to explain why the exchange rate fluctuations following the GFC differed notably in their impact on prices compared to exchange rate fluctuations between 2013-2015. The Covid-19 pandemic affected global supply chains (Liu, Shi, Yang & Zhang, 2023), and Russia's invasion of Ukraine has shocked global food supply chains (Abu Hatab, 2022). In a few years, two global shocks have occurred, and the impact of these shocks on ERPT in Sweden has not been investigated. As previous research has found global shocks to impact the inflation rate and the ERPT, it is relevant to explore how the recent global developments have affected the matters.

4 Methodology

In this paper, Bayesian VAR (BVAR) models are utilized. The estimation technique is more favorable than traditional VARs when data availability is limited, restrictions are desired, or uncertainty is associated with the estimates (Dieppe, Legrand & van Roye, 2016). When using BVAR, classic VAR assumptions are combined with a set of prior information (Enders, 2014). In traditional VARs, many parameters are included, possibly giving rise to the problem of over-parameterization. By using Bayesian methods, this issue can be avoided. There are a few different types of shrinkage priors, of which Minnesota priors are among the earliest developed.[1] The priors shrink the unrestricted, over-parametrized model and reduce the uncertainty associated with the estimation. Without the priors, impulse responses will be imprecise and standard deviations likely large. The priors are constructed using approximation, which allows for straightforward computation and a

[1]Minnesota priors assumes each variable follows a random walk process. When using macroeconomic data, the number of observations associated with each variable is likely numerous, making it challenging to attain estimates for each coefficient and likely leading to unknown parameters. The Minnesota approach replaces this unknown matrix of parameters with estimates (Koop & Korobilis, 2009).

flexible choice of priors. Other priors are inter alia natural conjugate priors and Wishart Priors (Koop & Korobilis, 2009).

BVAR models introduce restrictions on the included variables, making the results more closely tied to the underlying economic theory (Enders, 2014). Restrictions were first considered in a VAR model by Sims (1980). By implementing restrictions, one imposes conditions on how certain variables operate. BVAR models allow the variables to be affected simultaneously and introduce structural shocks (Enders, 2014). Different VAR models have been used in other publications where the ERPT is the topic of interest. This approach was preferred in inter alia Shambaugh's study in 2008, in Forbes, Hjortsoe, and Nenova's (2015) publication where the Euro area was the topic of investigation, and in Corbo and Di Casola's (2018) research where the ERPT in Sweden over the period 1995 to 2017 was investigated. Another approach is a VAR model with Cholesky decomposition, which is used by Faruqee (2006), Hahn (2003), Ito and Sato (2008), and McCarthy (2007). All the publications named above use the method to examine the pass-through of inflation shocks at different distribution stages.

For each specification, four outputs will be presented: impulse response functions, historical decomposition, forecast error variance decomposition (FEVD), and exchange rate pass-through (i.e., the ratio of the impulse response of prices to that of the exchange rate). The impulse response functions show a one-standard-deviation shock in the BVAR model (Dieppe, Legrand & van Roye, 2016). In other words, the impulses show the reaction of each variable following the six shocks separately. The FEVDs illustrate how much of each variable's forecast error variance is explained by each shock. For example, if the consumer price's FEVD assigns monetary policy shocks a value of 25 percent, an exogenous monetary policy shock can explain 25 percent of the consumer price's forecast error variance. The historical decomposition shows historical fluctuations in the series and the movements of the identified shocks across time (Dieppe, Legrand & van Roye, 2018). By observing the historical decomposition, the role of each shock for the variable of interest's deviation across time is detectable. For instance, using the historical decomposition enables us to disentangle how the importance of global shocks to exchange rate movements has been alternating over time. Lastly, the exchange rate pass-through allows for evaluating the ERPT conditioned on the nature of the shock. The estimate illustrates

how much of the exchange rate movement is transferred to the price level following each type of shock. The estimate sheds light on which type of shock has the most significant ERPT and illustrates that the fluctuating pass-through over time can be explained by the different types of shocks hitting the economy. For more details on estimating the exchange rate pass-through, see Section 6.1.

4.1 Restrictions

In VAR models, it is common to implement short-run restrictions, long-run restrictions, and sign restrictions. A development in implementing restrictions and identifying shocks is sign restrictions, which were first introduced by Uhlig (2005). This type of restriction has been brought forward as an alternative method when identifying VAR models, as sign restrictions are utilized to identify underidentified VAR models. The sign restrictions are based on economic theory and are chosen by the modeler (Binning, 2013). Simplified, sign restrictions restrict a shock to either cause an increase or decrease of other endogenous variables.

A method for improving the identification of the model is to combine sign restrictions with zero restrictions. Arias, Rubio-Ramìrez, and Waggoner (2014) introduced an approach where sign restrictions were strengthened by adding zero restrictions to some impulse responses. When imposing zero restrictions, it is possible to impose restrictions on impact and at longer horizons by utilizing so-called zero long-run restrictions. Zero long-run restrictions are helpful when the econometrician has a clear view of the economic relations' evolution. However, there is little economically founded consensus regarding forming structural impulse responses at longer time horizons. Therefore, few papers implement long-run restrictions (Korobilis, 2022). Due to the complications related to long-run restrictions, no zero long-run restrictions are implemented in this paper.

The impact of six types of structural shocks is considered in this study: Swedish demand shocks, Swedish supply shocks, monetary policy shocks, exchange rate shocks, global demand shocks, and global supply shocks. According to Forbes, Hjortsoe, and Nenova (2015), these six types of shocks should be sufficient to capture all shocks relevant to exchange rate fluctuations. The identification is based on sign restrictions and zero restrictions.

4.2 Identifying restrictions in the specification on consumer prices

The identifying restrictions in this specification follow Corbo and Di Casola (2018) and are presented in Table 1. Since Sweden is a small economy, Swedish domestic shocks are assumed to have zero effect on the global economy. The assumption follows the common belief that economic events in a small economy do not affect global prices and quantities. Further, the foreign variables are exogenous, implying that Swedish shocks do not influence the variables. Hence, Swedish shocks are restricted to not affect foreign CPI or GDP. The foreign variables' exogeneity is attained by implementing block exogeneity in the BVAR, creating partial exogeneity within the variables.

Following Corbo and Di Casola (2018), a global supply shock is restricted to having an immediate negative effect on prices for the first two quarters following the shock.[2] This two-quarter restriction is imposed to ensure that a technology-related shock is captured rather than some demand shock (Corbo & Di Casola, 2018). In other words, the effects on prices and quantities are opposite signs: if the global quantities increase, the prices decrease. This restriction aligns with previous literature, for example, Canova and de Nicoló (2003). A Swedish supply shock is restricted to affect Swedish CPI negatively, while Swedish GDP is positively affected. This sign restriction is motivated by the same reasoning as global supply shocks: when the quantities increase, prices decrease. A domestic demand shock positively affecting CPI and GDP is assumed to increase the interest rate as the central bank responds to the price inflation, and the currency is expected to appreciate.[3]

Table 1: Identifying restrictions, consumer price specification

	Exchange Rate Shock	SWE Demand Shock	Monetary Policy Shock	SWE Supply Shock	Global Demand Shock	Global Supply Shock
Exchange Rate	+	-	-			
Swedish CPI	+	+	-	-		
Monetary Policy	+	+	+			
Swedish GDP		+	-	+		
Foreign CPI		0	0	0	+	-
Foreign GDP		0	0	0		+

[2]The restrictions for all shocks except for a global supply shock are imposed on impact. Only for the global supply shock is the sign restriction imposed for the two quarters following a shock.

[3]The same restrictions are imposed by Forbes, Hjortsoe, and Nenova (2015) and Corbo and Di Casola (2018) following a positive domestic demand shock.

In the case of a monetary policy shock, increasing the interest rate, the Swedish GDP and CPI are assumed to decline while the exchange rate appreciates. Hjortsoe, Weale, and Wieladek (2016) motivated the restrictions imposed following a monetary policy shock and showed that the restrictions align with a classic small open-economy model. Lastly, in the case of an exchange rate shock, making the currency depreciate, the domestic CPI is assumed to increase. At the same time, the monetary policy responds by increasing the interest rate. These restrictions follow the premise that a depreciated currency increases the price of imports, which is passed on to consumer prices.

4.3 Identifying restrictions in the specification on import prices

Similar to Corbo and Di Casola (2018), in Table 2, an alternative specification is presented, where a measure for import prices is included. In the specification, foreign GDP is substituted by a measure for import prices.[4] Thus, in this specification, a global supply shock consists of a shock to import prices rather than a shock to foreign GDP. Including the import price variable makes it possible to assess the pass-through to import prices. The specification where import prices are included closely follows the identifying restrictions in the first specification and is motivated by the same underlying economic theory. However, some deviations from the previous specifications occur.

Table 2: Identifying restrictions, import price specification

	Exchange Rate Shock	SWE Demand Shock	Monetary Policy Shock	SWE Supply Shock	Global Demand Shock	Global Supply Shock
Exchange Rate	+	-	-			
Swedish CPI	+	+	-	-		
Monetary Policy	+	+	+			
Swedish GDP		+	-	+		-
Foreign CPI		0	0	0	+	
Import Prices	+	0	0	0		+

Following an exchange rate shock, making the Swedish krona depreciate, import prices are assumed to increase. As the domestic currency weakens, buying foreign goods becomes relatively more expensive, increasing the import prices. Consequently, a positive

[4]The previous specification is preferred when studying the ERPT to consumer prices as all types of shocks relevant to exchange rate movements are included (Forbes, Hjortose & Nenova, 2015). However, the setup of the current specification allows us to study the pass-through to import prices, in addition to the consumer prices.

sign restriction is imposed on import prices following an exchange rate shock. In this alternative specification, foreign GDP is, as stated above, no longer included. Therefore, a negative sign restriction is imposed on domestic GDP instead following a global supply shock to ensure that a quantity decrease arises simultaneously as prices increase.

4.4 Identifying restrictions in the specification on the frequency of price adjustment

In the final specification, the frequency of price adjustment is considered. In contrast to the previous specification, the frequency of price adjustment replaces domestic consumer price inflation, and a price adjustment frequency shock replaces the Swedish demand shock. The price adjustment frequency is considered a relevant channel for ERPT and has previously not been studied in similar setups. The frequency of price adjustment is closely related to consumer price inflation in Sweden (Ewertzh, Klein & Tysklind, 2022). Evidence suggests that the frequency increases following a rise in the price of imported goods due to, for instance, exchange rate movements (see Section 2.1). By including the frequency of price adjustment, it is feasible to examine the frequency fluctuations following differently-natured shocks and estimate the ERPT from the frequency price adjustment channel to consumer prices.

Table 3: Identifying restrictions, frequency of price adjustment specification

	Exchange Rate Shock	Price Adjustment Frequency	Monetary Policy Shock	SWE Supply Shock	Global Demand Shock	Global Supply Shock
Exchange Rate	+		-			
Frequency	+	+	-	-		
Monetary Policy	+		+			
Swedish GDP			-	+		
Foreign CPI		0	0	0	+	-
Foreign GDP		0	0	0		+

The identifying restrictions in this final specification closely resemble those in the first specification. The restrictions are presented in Table 3. The shocks and variables that are identical in the two specifications are given the same restrictions based on the same underlying economic theory. The price adjustment frequency shock is domestic and is therefore assumed to have zero effect on the global variables. This assumption follows the standard small-economy premises. No other restrictions are identified following this

type of shock, as previous research on the channel is scarce, and the paper aims to avoid unfounded restrictions lacking solid economic evidence. Since the frequency variable is closely related to domestic CPI (Ewertzh, Klein & Tysklind, 2022), equivalent identifying restrictions are imposed on the frequency variable as those on the Swedish consumer prices in Table 1. In brief, the frequency increase when the domestic currency depreciates following an exchange rate shock. When the policy rate increase is succeeding a monetary policy shock, consumer price inflation and, in this case, frequency react negatively. The same applies to a Swedish supply shock: when quantities increase, prices (frequencies) fall.

5 Data

The Bayesian VAR model is estimated using quarterly data from Sweden. The data sample covers the second quarter of 1995 through the last quarter of 2022. Thus, the data sample covers the inflation-targeting period until the present. The considered variables are the Swedish GDP, Swedish CPI, the monetary policy, the exchange rate, foreign GDP, foreign CPI, import prices, and the frequency of price adjustment. All series except the policy rate are included in first difference. The variables and data sources are described in Table C.2. The last two variables: import prices and frequency of price adjustment, are treated in the last two specifications. The inclusion of an estimate for import prices makes it possible to estimate how the exchange rate fluctuations affect those. Further, by involving the frequency of price adjustments, it is possible to examine whether a fluctuating currency affects the frequency of price adjustments and, later on, consumer prices.

Swedish consumer prices are measured using the inflation rate of the Consumer Price Index with a fixed interest rate (CPIF) from Statistics Sweden. This measure captures the inflation rate of consumer prices with fixed mortgage rates.[5] Data on Swedish GDP is collected from OECD. The monetary policy is estimated using data on the Swedish Central Bank's policy rate. The policy rate is de-trended using the Hodrick-Prescott filter. Over the investigated period, the policy rate has trended downward in Sweden and other advanced economies. As the downward trend is global and not specific to Sweden,

[5]CPIF has been the target variable of the Swedish Central Bank's monetary policy since 2017 (Sveriges Riksbank, 2023).

it can be seen as exogenous and removed from the estimation. The variable monetary policy is consequently obtained by subtracting the trend from the policy rate.[6]

The exchange rate is the nominal effective exchange rate index based on KIX weights.[7] A Swedish krona depreciation increases the index, whereas an appreciation decreases the index. Foreign GDP is a weighted average of Sweden's main trading partners. The variable is obtained using the KIX weights and quarterly data on GDP from OECD. Foreign consumer prices are captured by a weighted average using the KIX weights on quarterly consumer price index data from OECD. The variable is included in the first specification: the specification on consumer prices. In the second specification, on import prices, foreign GDP is replaced by a measure capturing global export prices based on Statistics Sweden's import price index for imports of goods and services.

The variable capturing frequency of price adjustment is based on daily price data covering four global retailers. The data is available at the Billion Prices Project Dataverse and was collected by Cavallo, Neiman, and Rigobon (2014). The data provides daily price coverage from 2008 to 2013 in 85 countries, including Sweden. The four global retailers are Apple, H&M, IKEA, and Zara. It would have been beneficial to acquire data on a broader set of products as the frequency of price adjustment is heterogenous across sectors and products. Further, a more extended data period would have been preferred. Consequently, in future research, I suggest the usage of data covering a broader set of products and a longer period. However, the data attained covers four retailers with extensive global coverage and captures an interesting period: the Global Financial Crisis.

The frequency measure is attained by observing if and when a price of a specific product changes. The frequency measure is defined as:

$$Frequency_i = \frac{No.\ of\ Price\ Increases_i + No.\ of\ Price\ Decreases_i}{Total\ No.\ of\ Prices_i} \tag{2}$$

In words, the frequency of price adjustment for each product i is the total number of

[6]Forbes, Hjortsoe, and Nenova (2015) use a similar approach to UK data, as do Corbo and Di Casola (2018) on Swedish data.

[7]The KIX is a geometric index with weights based on bilateral exchange rates. It covers 32 countries that are important for Sweden in terms of trade. For more information on the index, see https://www.riksbank.se/en-gb/statistics/search-interest--exchange-rates/explanation-of-the-series/effective-exchange-rate-indices/.

price increases of product i plus the total number of price decreases of the same product, divided by the total number of price observations of the product. After estimating the frequency for each product, the mean frequency is estimated, giving the aggregated frequency measure used in the estimation.[8]

Identical definitions for frequency are used by Nakamura, Steinsson, Sun, and Villar (2018), Klenow and Krytsov (2008), and Wulfsberg (2009). The price adjustment frequency is graphed along CPIF in Figure 1. Further, the frequency of price increases and price decreases are considered separately. This separation is executed following evidence suggesting that the frequency of price increases varies with the inflation rate, whereas the frequency of price decreases is unresponsive (Nakamura et al., 2018). The frequency of price increases and decreases are graphed alongside consumer price inflation in Figure B.1.

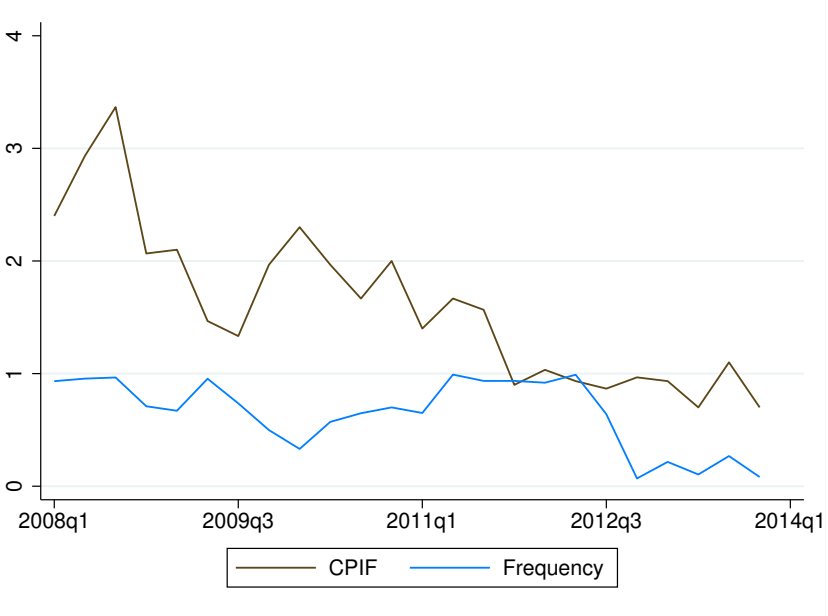

Figure 1: Frequency of price adjustment & CPIF

6 Estimation technique

Bayesian VAR models in first differences are estimated with two lags and Minnesota-style priors. Sign and zero restrictions are introduced following the algorithms that Arias,

[8] As the frequency measure differs for each product i, estimating the weighted average rather than the mean frequency would have been favorable. The weighted average could have been estimated using, for instance, an expenditure-weighted mean or a mean based on sold quantities. Unfortunately, the data used only contain price observations, and a weighted-average measure can therefore not be obtained.

Rubio-Ramirez, and Waggoner (2014) developed. The estimations are based on 2000 iterations, with 200 burn-ins. The Bayesian Estimation, Analysis and Regression (BEAR) toolbox, developed in MATLAB, performs the analysis.[9] The hyperparameters[10] are set as follows: the one about overall tightness as $\lambda_1 = 0.2$, the hyperparameter capturing cross-variable weighting as $\lambda_2 = 0.5$, the one about lag decay is set to $\lambda_3 = 1$, and the one about exogenous variable tightness as $\lambda_4 = 0.01$.[11]

6.1 Estimating exchange rate pass-through

To compare the ERPT over time and related to different types of shocks, the focus lies on the ratios of the impulse responses. The investigation is executed by estimating the ratio of the impulse responses of prices to the exchange rate for each shock s. Corbo and Di Casola (2018), Forbes, Hjortsoe, and Nenova (2015), and Shambaugh (2008) apply a similar approach. The computation is given by:

$$ERPT_{s,t} = \frac{\sum_{j=0}^{t} \Delta Price}{\sum_{j=0}^{t} \Delta ExchangeRate} \tag{3}$$

The measure captures the total effect over all included periods t of the exchange rate movements. The ratios are calculated using the 1800 sets of impulse responses saved after discarding the initial 200. All shocks used in the computation are manipulated to cause a depreciation of the exchange rate. This manipulation is done to facilitate the comparison of the shocks.[12]

7 Results

In the following sections, the attained results are presented and discussed.[13] Corbo and Di Casola's (2018) study is replicated in the first specification, albeit with an extended

[9] The BEAR toolbox allows for forecasting and policy analysis and is a MATLAB-based toolbox. The toolbox is developed for "state-of-the art research" (Dieppe, Legrand & van Roye, 2016, p. 1). It includes functions such as conditional forecasts, different prior distributions, and sign and magnitude restrictions.

[10] A hyperparameter is a parameter of the prior distribution, i.e., the coefficients that parameterize the prior distribution (Giannone, Lenza & Primiceri, 2012).

[11] The hyperparameters are set to the same values as in Corbo and Di Casola (2018).

[12] The impulses are manipulated to create a depreciation by switching the sign of those shocks that create an appreciation. This manipulation can be implemented as the impulse responses are symmetrical (Dieppe, Legrand & van Roye, 2018).

[13] The forecast error variance decompositions are presented and commented on in Appendix A.

period (2018-2022).[14] The extended period covers the Covid-19 pandemic and Russia's invasion of Ukraine, involving economic uncertainty, global supply chain disruptions, and high inflation rates. The unique nature of this period makes it particularly interesting to study, as it is feasible that ERPT has exhibited a different behavior during these years. The second specification, where import prices are examined, likewise replicates Corbo and Di Casola's (2018) estimations. The third specification presents a novel setup. The specification considers the frequency of price adjustment to assess how the channel is affected by differently-natured shocks and investigates the ERPT from the frequency of price adjustment to consumer price inflation.

7.1 The specification on consumer prices

7.1.1 Impulse response functions

The impulse response functions are presented in Figure 2. In addition to the median response, the Figure reports the 68 percent probability bands. The impulse responses resemble those received by Corbo and Di Casola (2018), although the magnitude differs slightly. The diverging magnitudes can be related to the disparate periods. The following behaviors are observed when examining the impulses following an exchange rate shock: in line with the imposed restrictions, an exchange rate shock making the Swedish krona depreciate causes an initial increase in Swedish consumer price inflation and the policy rate. Further, the shock generates an initial decline in the Swedish GDP. A positive Swedish demand shock increases domestic consumer price inflation and causes an exchange rate appreciation. Besides the increasing inflation rate, Swedish GDP incline. The repo rate is pushed upwards as a response to the increased inflation. The initial increase of consumer price inflation only remains for a few quarters, while the repo rate remains inclined for a more extended period.

Moving on to a positive Swedish supply shock: a positive shock that increases GDP leads to a weakened Swedish krona while consumer prices decline over a long horizon. A slight increase in the policy rate accompanies these impulses. The named responses do not align with the Uncovered Interest Rate Parity (UIP) condition. If the condition had held, the repo rate increase would have made the Swedish currency more attractive and hence

[14] The robustness of the results are tested, see Appendix C.1.

caused an appreciation. However, the 68 percent probability bands of the currency and the repo rate include zero, making caution necessary when interpreting the reactions. An initial exchange rate appreciation appears following a Swedish monetary policy shock that increases the policy rate. The appreciation is in line with the UIP condition. The increased repo rate makes the Swedish GDP and consumer price inflation fall. These declines align with the expected behavior of the variables following a rise in the repo rate.

Finally, the two global shocks are examined. A positive global demand shock causes an increase in both foreign and Swedish consumer price inflation. The reaction of the exchange rate is essentially nil, while the repo rate increases slightly after a few quarters. The increasing repo rate is a conventional reaction to tackle the increased inflation. Following a positive global supply shock, causing a rise in foreign GDP, a fall in foreign consumer prices emerges.

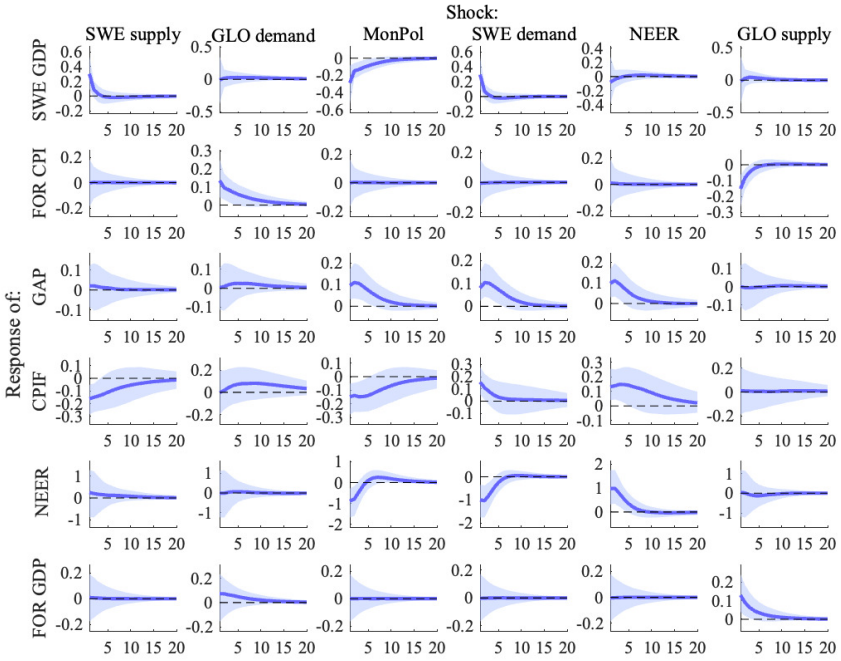

Figure 2: Impulse responses, consumer price specification

7.1.2 Historical decomposition

Figure 3 shows the historical decomposition of the exchange rate. As evident in the forecast error variance decomposition in Figure A.1, exchange rate shocks and Swedish

demand shocks have been essential components behind the exchange rate movements. Further, Swedish monetary policy shocks have been influential drivers of the fluctuations, notably in times of considerable uncertainty, such as after the GFC, post the pandemic, and Russia's invasion of Ukraine.

The importance of global shocks increased during the financial crisis. Before the GFC, global demand shocks explained a limited part of the exchange rate movements. However, post the crisis, the components' importance has expanded. The growing influence of global shocks during the crisis aligns with previous research (see Corbo & Di Casola, 2018; Hopkins, Lindé & Söderström, 2009). In addition, Swedish demand shocks were a critical component during the crisis. This result aligns with Forbes, Hjortsoe, and Nenova (2017). During the zero- and negative repo rate years around 2015, the monetary policy explained a significant part of the exchange rate depreciation. Consistent with the UIP condition, the currency depreciated when the policy rate was low.

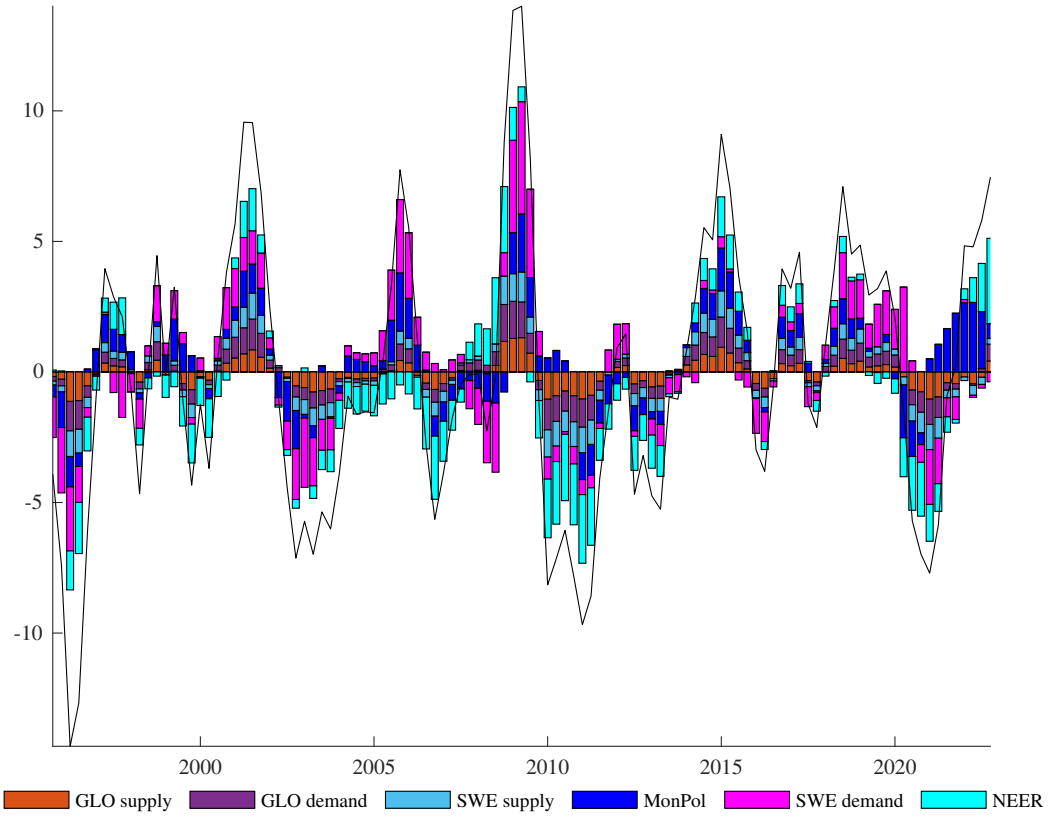

Figure 3: Historical decomposition of the Swedish exchange rate, consumer price specification

From 2018 and onwards, some patterns worth noting are exhibited. The appreciation in

2020, followed by a significant depreciation, was generally due to exchange rate shocks and, as mentioned above, monetary policy shocks. The Swedish policy rate was nil during the period, which appears to have been driving the depreciation. This finding aligns with the UIP condition. In addition, global supply shocks were significant during the pandemic. This finding is legitimate, given the disruptions in global supply chains following the spread of the virus.

Figure 4 presents the historical decomposition of CPIF inflation. Viewing the figure, it is evident that monetary policy shocks have been the most crucial driver. The gravity of monetary policy shocks aligns with the forecast error variance decomposition, where monetary policy shocks explain between 19 and 26 percent of consumer price inflation.[15] The two global shocks explain a little less than 30 percent of the movements across time. During the GFC, the importance of monetary policy shocks to inflation fell while global demand shocks, Swedish demand shocks, and exchange rate shocks gained significance. This finding aligns with Corbo and Di Casola (2018). A fall in the influence of monetary policy shocks is likewise visible in the low inflation years pre-2015. The Swedish Krona was relatively strong during these years, contributing to the low inflation rate. In 2015, the Swedish Central Bank adopted a negative repo rate, which stimulated the inflation rate in concerned years.

The negative global supply shocks during the Covid-19 pandemic contributed to low consumer price inflation. Post the pandemic, global demand shocks have increased the consumer price inflation. Initially, the increased global and Swedish demand stimulated inflation. Gradually, as the world opened up and restrictions were abolished, global supply shocks have become more important drivers of inflation. The increased importance of exchange rate shocks was further visible last year. In contrast to earlier periods, global shocks explained approximately two-thirds of the inflation in 2022. Consequently, there is a tendency for a shift in the importance of the different shocks post the pandemic. This finding, which suggests an altered trend, is novel as no previous studies, that I know of, have examined the decomposition of consumer prices in Sweden in this period.

[15]The importance of monetary policy is more prominent than in other studies on the Swedish economy. For example, Corbo and Di Casola (2018) found a magnitude of approximately 10 percent, while Adolfson, Laseén, Lindé, and Villani (2007) found a magnitude of approximately 9 percent.

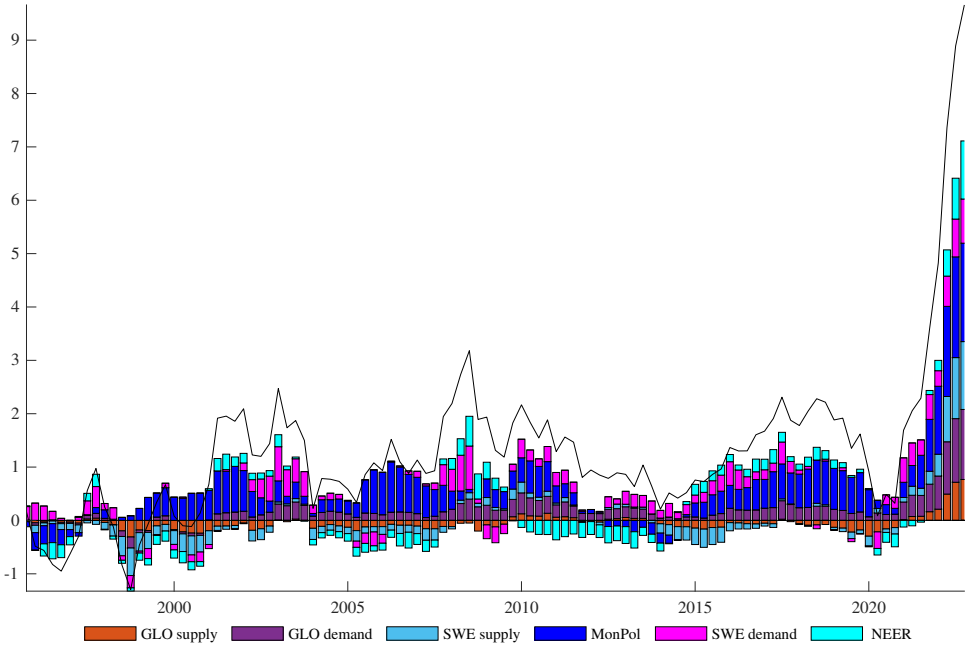

Figure 4: Historical decomposition of the CPIF inflation, consumer price specification

7.1.3 Exchange rate pass-through

The ERPT related to different types of shocks is illustrated in Figure 5. In the following section, the focus lies on the median ratio of the impulse responses. The impulses are manipulated so to cause a depreciation of the exchange rate. Consequently, negative global shocks, monetary policy shocks, and domestic demand shocks are studied.

When observing Figure 5, it is visible that there are dynamic movements in the ERPT in the first five quarters in particular, while the ERPT from monetary policy shocks is volatile over the first eight quarters. After the first two years, the ERPT appears constant. The average represents the average ERPT, and is attained by weighting the shocks with their share of the forecast error variance decomposition of the exchange rate. The average pass-through fluctuates around 2 percent after two years, which is slightly lower than the 3 percent pass-through found by Corbo and Di Casola (2018). However, this paper captures five additional years in which the consumer price inflation and the exchange rate have been particularly volatile, which can explain the difference.

The ERPT to consumer prices is the highest following an exchange rate shock. The pass-through fluctuates around 20 percent after the initial dynamics. This estimate is

notably more prominent than the ERPT found by Corbo and Di Casola (2018), who found a pass-through after an exchange rate shock of approximately 10 percent. The higher estimate is presumably a cause of the recent high consumer price inflation, for which exchange rate shocks have been significant contributors. After eight quarters, global supply shocks create the second largest ERPT of approximately 7 percent. Following the increase in foreign consumer prices created by negative foreign supply shocks, and a weak Swedish krona, domestic firms' imports become more costly. The cost is passed on to the consumers to cover the increased production costs and avoid negative profits. The ERPT following a monetary policy shock demonstrates erratic behavior. In the second year following a negative monetary policy shock, the ERPT is high and varies between 11 and 19 percent.

The pass-through is negative following both a domestic and a global demand shock. The negative pass-through implies that after a negative demand shock, firms are unwilling to pass on the increased production costs to the customers, even if the Swedish currency depreciates—instead, both negative shocks lower consumer prices. The ERPT, following a global demand shock, stabilizes at approximately -15 percent after the first two years. The ERPT following a domestic demand shock is approximately -3 percent.[16]

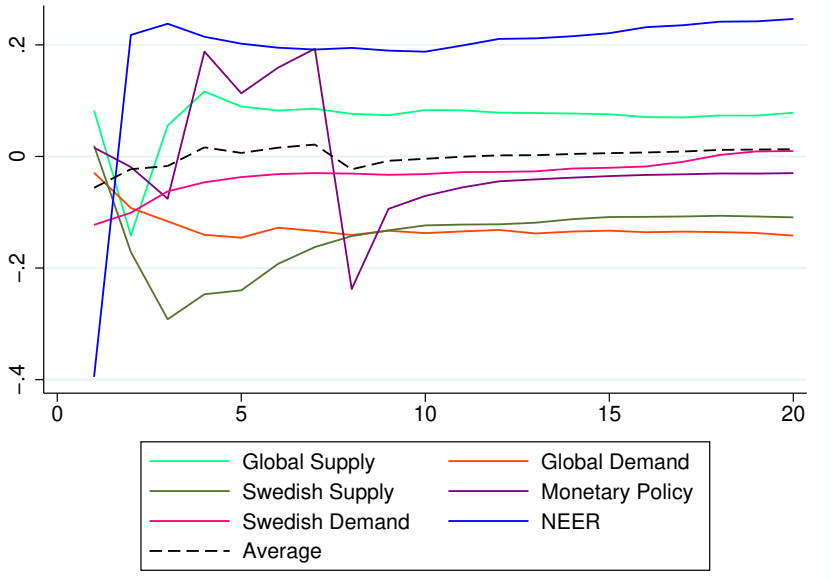

Figure 5: Exchange rate pass-through to CPIF, consumer price specification

[16]The ERPTs' magnitude following both demand shocks align with Corbo and Di Casola's findings (2018).

A Swedish supply shock has a negative ERPT. This ERPT is of a more negative magnitude than what Corbo and Di Casola (2018) found. In 2022, Swedish supply shocks were a relatively large driver behind consumer prices (see Figure 4). Feasibly, the shock's increased impact can lie behind the diverging estimates. However, the probability bands for the repo rate and the exchange rate following a domestic supply shock contain zero (see Figure 2), and therefore, the estimation should be interpreted cautiously.

After examining the results from the first specification, some results confirming previous literature are found: I) The Swedish variables have been particularly sensitive to global shocks during financial uncertainty. II) As displayed in 2003 to 2004, 2006, and 2020 to 2021, the price level is less sensitive to appreciations than to depreciations. III) Exchange rate movements do create pass-through to consumer prices, and consumer price inflation increases after an exchange rate shock that depreciates the currency. IV) Negative demand shocks generate negative pass-through to consumer prices.

7.2 The specification on import prices

In the second specification, import prices are included in the estimation. Most impulse responses in this specification look similar to that obtained in the first specification. The impulse responses are further discussed and presented in Appendix A.2.

7.2.1 Historical decomposition

Figure A.4 shows the historical decomposition of the exchange rate fluctuations, while consumer price's historical decomposition is presented in Figure A.5. The impact of each type of shock is roughly equal to that in the previous specification. The historical decompositions of the exchange rate and the consumer prices are further covered in Appendix A.4.

The role of each shock for the deviation across time of the import price inflation can be seen in the import price's historical decomposition in Figure 6. Over time, the most crucial driver of import prices has been exchange rate shocks. Exchange rate shocks have been especially dominant between 1996-2000, 2010, 2014, and 2022. These years coincide with large exchange rate movements. This finding implies that the ERPT is larger in times of significant exchange rate deviations. In early 2000, two notable import price

hikes were visible: one around 2000 and one around 2005. The import price hikes were primarily explained by global shocks, which aligns with Corbo and Di Casola's (2018) results. Exchange rate shocks mainly caused the increased import price around the GFC. As seen in Figure A.4, the Swedish currency depreciated significantly around the GFC, increasing the cost of imports.

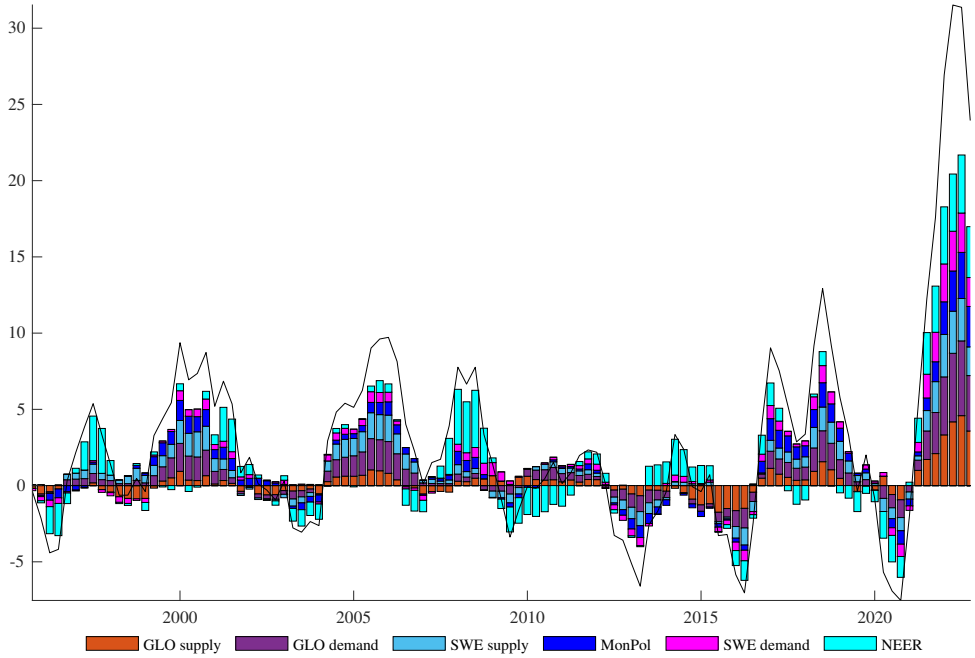

Figure 6: Historical decomposition of import price inflation, import price specification

Global shocks have been the essential driver during the recent import price boom. In these years, foreign inflation has increased due to global disruptions such as the pandemic, Russia's invasion of Ukraine, and increased transportation costs following rising energy and fuel prices. The increased costs have affected both foreign inflation and import prices. In addition, the Swedish currency depreciated in 2022, making imports even more expensive.

7.2.2 Exchange rate pass-through

To study the ERPT to import prices versus consumer prices, the ratio of price responses to that of the exchange rate is computed. Analogous to the previous specification, the impulses are manipulated to cause exchange rate depreciations. Henceforth, all but the exchange rate shocks are negative.

The ERPT to import prices is illustrated in Figure 7. The figure shows the median ratio of cumulative responses of import prices relative to the exchange rate. The average ERPT to import prices is virtually zero. Following a negative monetary policy shock, import prices increase. The falling repo rate makes the currency depreciate, raising the relative price of imports. The same applies to exchange rate shocks: a positive exchange rate shock depreciates the currency and has a positive ERPT to import prices at a short horizon.

Domestic supply shocks and domestic demand shocks have opposing ERPTs. Initially, a negative Swedish supply shock lowers the quantities while the price of imported goods increases. After approximately two years, the ERPT is instead negative. However, as shown in Figure A.2, the exchange rate response following a domestic supply shock is not different from zero. Hence, this movement should be interpreted with some caution. A negative Swedish demand shock, lowering domestic inflation, has a negative ERPT to import prices in the initial five quarters. The decreased import prices at impact may be due to the lowered demand. Following both a negative global demand shock and a negative global supply shock, the ERPT to import prices is negative. Consequently, the falling global prices are reflected in the import prices - overall inflation decline.

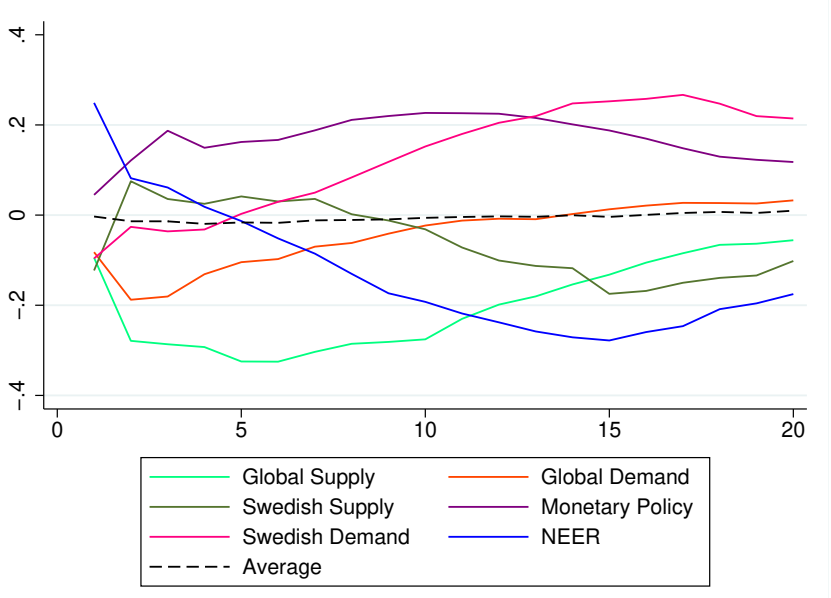

Figure 7: Exchange rate pass-through to IMPI

The computation of ERPT to consumer prices where import prices are included is presented in Figure 8. The average pass-through varies around 3 percent in the first two

years. In the long run, the pass-through varies between 6 and 8 percent. To generate a depreciation following a monetary policy shock, the policy rate declines in accord with the UIP condition. A negative monetary policy shock has an ERPT to consumer price inflation of approximately 20 percent in the first two years. A negative monetary policy shock likely occurs as a tool to stimulate inflation. If the procedure is successful, inflation and demand are stimulated.

Similar to the previous specification, exchange rate shocks has a positive ERPT. Thus, exchange rate shocks, causing a depreciation, increase domestic inflation. However, the effect is diminishing over time. At a long horizon, the ERPT following exchange rate shocks to consumer prices is approximately 5 percent, which aligns with Corbo and Di Casola's (2018) findings. A negative Swedish supply shock brings falling domestic supply and depreciation of the Swedish krona. Falling quantities are united with increased prices. Both negative demand shocks: domestic and foreign, generate negative pass-through to consumer prices in the first year. Interestingly, the ERPT following a negative Swedish demand shock switch sign after a few years. This dynamic may be due to the increased costs of import prices following a weakened domestic currency. As seen in Figure 7, the ERPT to import prices following a negative domestic demand shock is positive in the long run. This positive pass-through is likely transferred from firms to consumers in later distribution stages.

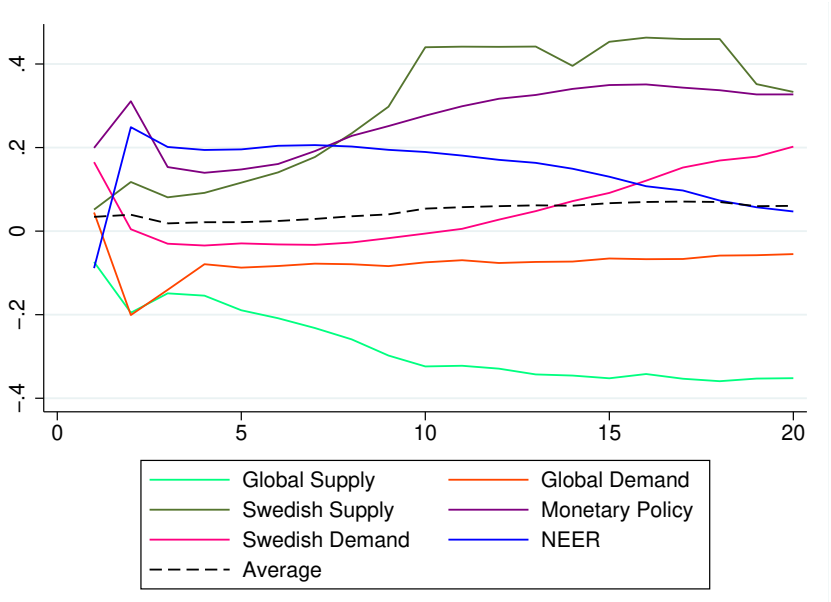

Figure 8: Exchange rate pass-through to CPIF, import price specification

The findings in Section 7.2 align with previous literature on exchange rates and import prices. Previous literature suggests that the import and consumer prices rise following a domestic currency depreciation, as the weakened currency makes the imported goods more expensive. This belief is confirmed by the positive ERPT to import and consumer prices and the exchange rate's contribution to the decomposition of prices at times of depreciation.

7.3 The specification on frequency of price adjustment

7.3.1 Impulse response functions

The final specification considers the role of the frequency of price adjustment on consumer price inflation. The frequency is computed according to Equation 2. The following section discusses the impulse responses following a frequency shock and the frequency variable's reaction to alternative shocks. Besides the definition provided in Equation 2, the impulse responses associated exclusively with the frequency of price increases versus the frequency of price decreases are estimated. This separation is conducted since the comovement between the frequency of price decrease and inflation has differed from that between the frequency of price increase and inflation (see Section 5). However, the impulse responses following the two types of frequencies are similar, and no distinction regarding their impact on inflation is visible (see Figure B.2, Figure B.3).

The impulse response functions are presented in Figure 9. Following the two global shocks, the included variables react similarly to the previous specifications: the prices fall following a supply shock that increases the quantities, while a global demand shock, raising inflation, is accompanied by an increased repo rate. The frequency is unaffected. The exchange rate shocks increase the frequency of price adjustments. The depreciated currency makes the imports more expensive. To keep constant markups, the firms must increase consumer prices. Parallel to the increased frequency, the repo rate increase. The frequency's close relationship with inflation suggests increased consumer prices. Hence, the central bank reacts to inflation by increasing the policy rate.

A domestic supply shock generates corresponding responses as in the earlier specifications. A supply shock, raising the quantities, creates a fall in the frequency of price adjustment. When quantities increase, firms face increased competition and can accordingly not in-

crease the frequency of prices as this would endanger their market power (see Section 2.3). After a monetary policy shock, the Swedish krona is strengthened. The frequency of price adjustment reacts to the shock by decreasing. An increased interest rate dampens consumer price inflation while simultaneously appreciating the currency, consistent with the UIP condition. Both effects contribute to a lower price adjustment frequency as the demand fall and the firms' costs decline. Following a frequency shock, a similar pattern is visible: the policy rate increases, and the exchange rate appreciates.

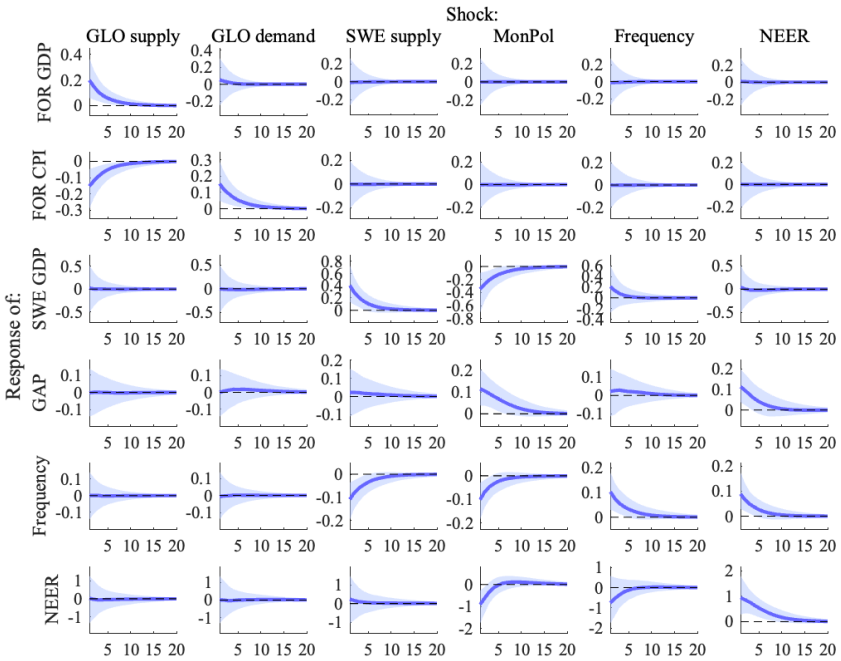

Figure 9: Impulse responses, frequency of price adjustment specification

7.3.2 Historical decomposition

Figure 10 shows the contribution of each type of shock to the exchange rate's deviation. Many fluctuations, especially in the early part of the sample, are driven by exchange rate shocks. Global shocks consistently explain a large share of the movements, with their importance notably articulated at times of more significant fluctuations. Monetary policy shocks have had varying importance to the exchange rate movements. Between 2010 and 2012, its contribution was limited, whereas monetary policy shocks were among the primary drivers behind the depreciation in 2009. In 2009 the repo rate was substantially lowered, contributing to the depreciation.

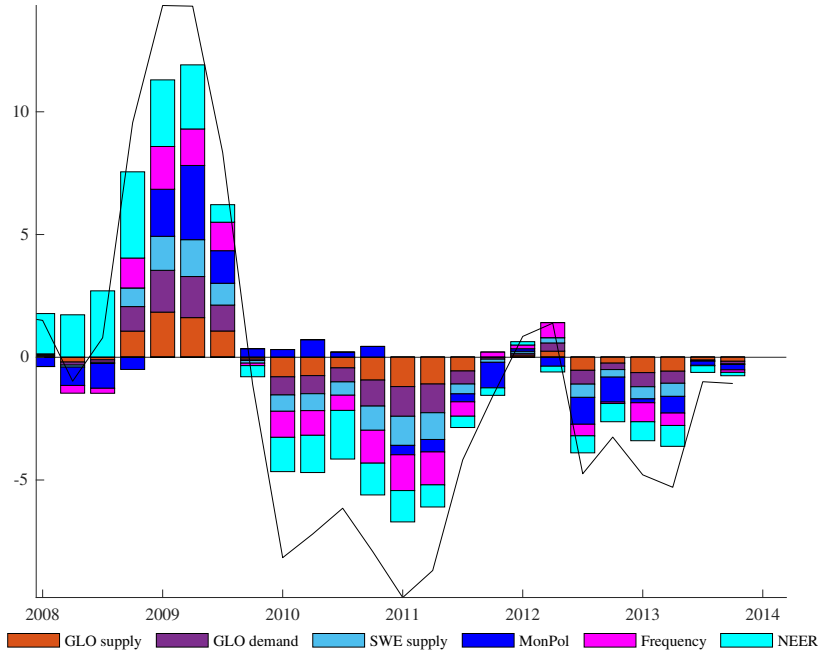

Figure 10: Historical decomposition of the Swedish exchange rate, frequency of price adjustment specification

The frequency of price adjustment's historical decomposition is presented in Figure 11. The frequency peaks around the GFC and in 2011. During the GFC, consumer and import price inflation were high, while the Swedish krona was weak. The higher frequency at this time follows previous findings suggesting that the frequency is high when there are large movements in commodity prices (see Section 2.1). Further, the importance of global shocks to the frequency's deviation is more distinguished when the deviations are large, a finding that aligns with Sweden's vulnerability to global shocks (Corbo & Di Casola, 2018).

Exchange rate shocks' contribution to the frequency of price adjustment is diversified. Its importance is notably articulated during the GFC. As described above, the Swedish exchange rate was weak while the consumer price inflation was high. The weak currency causes relatively more expensive imports, making importing firms increase consumer prices to stabilize their markups. Around 2010, the Swedish krona was strengthened. The strengthening is reflected in a lower frequency of price adjustments. The described behavior supports the information in Section 2.1. The importance of monetary policy shocks were the most significant in 2009 and 2010. The falling policy rate in 2009 initially

increased the frequency of price adjustment through its stimulating effect on the inflation rate. In contrast, the relatively high repo rate in 2008 had a dampening effect on the frequency of price adjustment. This behavior aligns with previous evidence on the relationship between the frequency of price adjustment and inflation (see for example, Ewertzh, Klein & Tysklind, 2022; Wulfsberg, 2009).

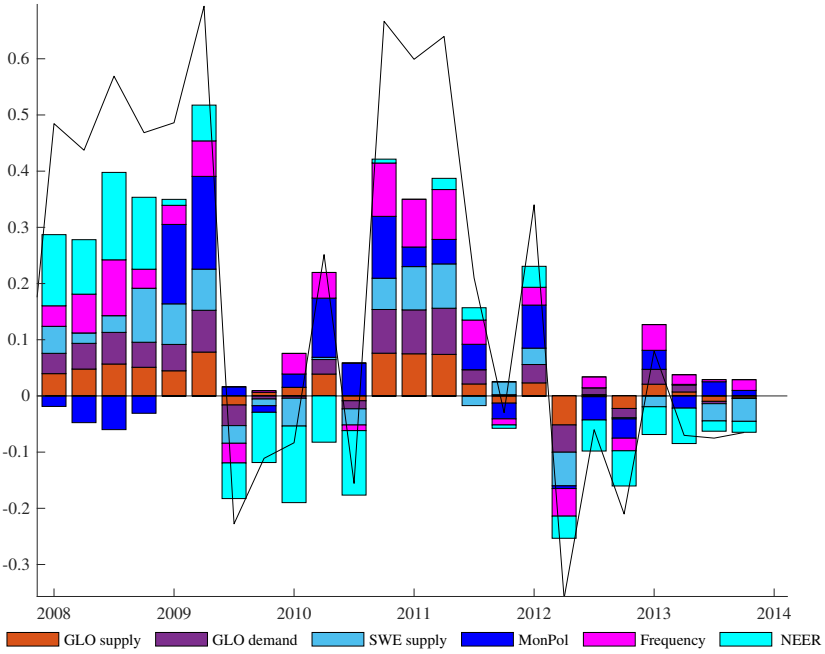

Figure 11: Historical decomposition of the frequency of price adjustment

7.3.3 Exchange rate pass-through

The ERPT is presented in Figure 12. Analogous to previous specifications, all impulses are manipulated to cause an exchange rate depreciation. In the following section, the exchange rate and domestic supply shocks are positive, while the remaining shocks are negative. The average ERPT is approximately 2 percent after two years, similar to the ERPT found in the first specification. Over time, the average ERPT increases and finally stabilizes around 4 percent. Generally, the ERPTs are of lower magnitudes than in the previous specifications.

Figure 12 suggests a volatile and constrained ERPT following a negative frequency shock. In the first eight quarters following the shock, the ERPT varies between -3.5 and -0.5 percent. After two years, the sign is reversed, and the ERPT is instead positive. In year

three, the ERPT is approximately 1 percent, while the ERPT increases to 6 percent at a long horizon. The estimate for the frequency of price adjustment includes four large global firms with significant market shares. It is feasible that due to their large market shares, the ERPT is limited as large firms tend to source inputs globally (see Section 2.3). Thus, if a more diverse set of firms had been included, the ERPT might have looked different. By contrast, previous studies suggesting a U-shaped relationship between firm size and ERPT imply a large ERPT from these firms (Devereux, Dong & Tomlin, 2017). For instance, Apple had approximately 20 percent of the market share of smartphone shipments in 2011 (Statista, 2023).

Among all shocks, an exchange rate shock has the most significant positive ERPT to consumer prices, aligning with the result in the first specification. The ERPT is the second most prominent following a negative monetary policy shock. A falling repo rate depreciates the currency, making imported components more expensive. The increased costs of imports are spread to an increased frequency of price adjustment and a higher consumer price inflation. Negative global shocks feature positive ERPTs initially. However, the ERPT following a negative global supply shock is negative at a longer horizon. A positive domestic supply shock, increasing the quantities while weakening the currency, has a negative ERPT. Presumably, the increased domestic quantity and weaker currency decrease the need and demand for foreign goods, making the ERPT to consumer prices modest.

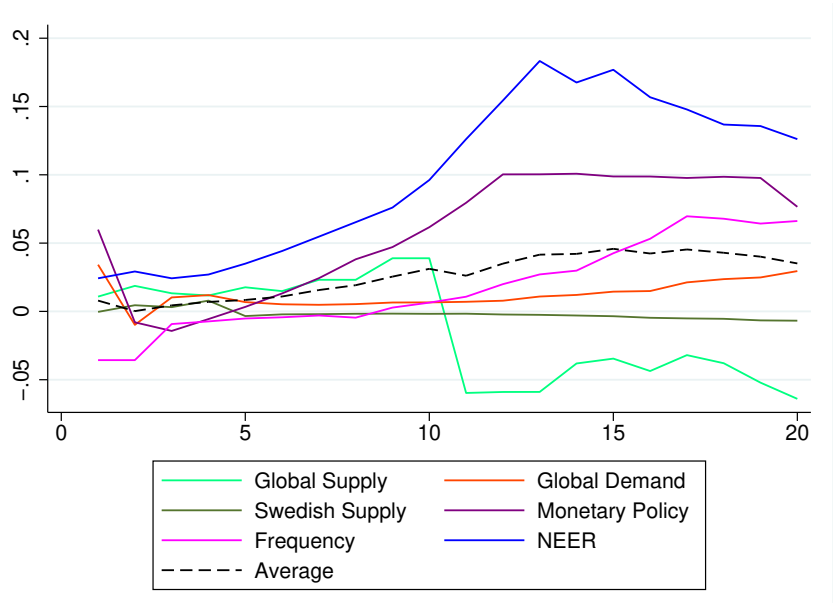

Figure 12: Exchange rate pass-through to CPIF, frequency of price adjustment specification

Some findings in the third specification support the literature and theoretical theory regarding the frequency of price adjustment, exchange rates, and the inflation rate: I) A higher frequency of price adjustment is exhibited when the price of commodity products is volatile, which aligns with the frequency's close relationship with commodity cost volatility found in previous research. II) Global shocks are of more considerable importance for the frequency in times of economic uncertainty. This result supports previous literature highlighting Sweden's vulnerability to global shocks. III) Exchange rate shocks explain 20 percent of the movements in the frequency of price adjustment, promoting the objective that falling markups lead to an increased frequency of price adjustment. When firms' markups fall due to increased costs of imported intermediate goods caused by a weaker domestic currency, the higher costs are transmitted to a higher frequency of price adjustments. IV) The ERPT to consumer prices following a frequency shock is volatile and limited. As the measure only includes four large firms, the discovery aligns with the perception that large global firms have low ERPT.

8 Conclusion and discussion

Exchange rates fluctuate, contributing to pass-through to import and consumer prices. There is no common consensus on why the movements of exchange rates have different impacts on price levels over time—making it demanding for central bankers and others who must assess how the exchange rate fluctuations influence the inflation rate. The Swedish krona has weakened in the last decade, and in January 2023, the currency was the weakest it has been in over 14 years. The weak currency and recent high inflation levels make the exchange rate pass-through (ERPT) issue relevant for Sweden.

This thesis investigated ERPT from the Swedish currency to import and consumer prices and the impact of the frequency of price adjustment on consumer prices. The latter subject has not, to my knowledge, been examined in similar setups. The study covers 1995 to 2022, capturing events such as the Global Financial Crisis, negative central bank rates from 2015 to 2019, the Covid-19 pandemic, and Russia's invasion of Ukraine. As exchange rates and their associated pass-through fluctuate more in times of uncertainty, these periods are of particular interest. Bayesian vector autoregression models with sign and zero restrictions were estimated. Four domestic and two global shocks were incorporated

into the estimation. The approach was utilized on three different specifications.

The usage of three specifications allowed for studying three different matters: ERPT to consumer prices, import prices and the relationship between consumer prices and the frequency of price adjustment. The first specification allowed for examining the ERPT to consumer prices following four domestic and two global shocks. These six shocks have all been deemed critical when examining ERPT in previous literature. The second specification showed how exchange rate movements are passed on from import to consumer prices, and allowed for testing the robustness of the results to different identifying restrictions and data. The third and final specification illuminated how the frequency of price adjustment conforms following differently-natured shocks and the relationship between the frequency channel and consumer prices.

The results imply that the average ERPT to consumer prices is approximately 2 percent. Nevertheless, the impact varies significantly with the type of shock, which highlights the limitations of using a univariate or "rule-of-thumb" approach to study the ERPT. Monetary policy and exchange rate shocks have the highest positive ERPT to consumer prices, while monetary policy shocks have the highest positive ERPT to import prices of approximately 20 percent. Following negative demand shocks, the ERPT to consumer prices is negative. This finding implies that firms' price-setting behavior is more driven by the diminishing demand than the increased costs associated with the exchange rate fluctuation following these shocks. Furthermore, post the pandemic, a shift in the gravity of the shocks is distinguishable, with global shocks and exchange rate fluctuations explaining a larger share of consumer price variations.

Variance in the frequency of price adjustment is explained to 33 percent by global shocks, with the global shocks' importance notably pronounced during the Global Financial Crisis. The impact of a changing frequency of price adjustment on consumer prices is highly volatile and has a maximum ERPT to consumer prices of 6 percent. The data on the frequency of price adjustment used in the present study covers a limited period and few firms. As the channel appears to impact the ERPT to consumer prices and depends on exchange rate fluctuations, future investigations using a more extensive dataset are encouraged.

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A Appendix, Forecast error variance decomposition and impulse response functions

A.1 Forecast error variance decomposition, consumer price specification

In Figure A.1, the forecast error variance decomposition (FEVD) is presented. The exchange rate shock explains approximately 20 percent of the exchange rate fluctuations in the specification. Approximately 28 percent are explained by global shocks. The remaining 52 percent of the exchange rate fluctuations are explained by the Swedish supply shock, the Swedish demand shock, and the monetary policy shock. The FEVD is similar to that Corbo and Di Casola (2018) obtained. The exchange rate shock is given roughly the same magnitude of importance. However, global shocks explain a larger share in the current study (28 percent versus 20 percent), while domestic shocks explain a smaller share (52 percent versus 58 percent). The more considerable importance of global shocks can conceivably be attributed to recent global developments.

The FEVD suggests that a little more than 30 percent of the CPIF inflation's variance decomposition is explained by global shocks. The most significant contributor is Swedish monetary policy shocks (approximately 25 percent), while the remaining domestic shocks explain approximately 42 percent.

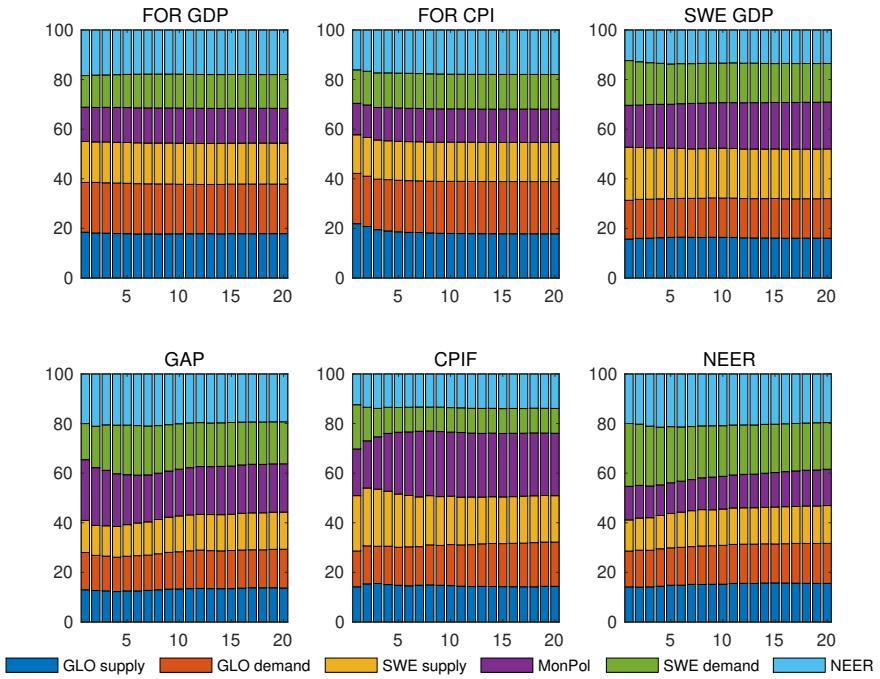

Figure A.1: Forecast error variance decomposition, consumer price specification

A.2 Impulse response functions, import price specification

Figure A.2 presents the impulse responses when import prices are included in the estimation. Most impulse responses in this specification look similar to that obtained in the first specification. The following section will analyze the responses that diverge from Figure 2 and the responses of import prices.

The response of import prices differs depending on the shock. As domestic supply increases, import price increase. An increased policy rate creates a fall in import prices, feasibly due to the appreciation of the exchange rate occurring. In contrast, import prices increase following an exchange rate shock and a global supply shock. Following an exchange rate shock, weakening the currency, imported goods invoiced in foreign currencies become more expensive, raising the import prices. The increasing consumer prices suggest that the firms' increased import costs are passed on to consumers. A global supply shock, which now captures import prices, has different impacts than the shock in the previous specification. The increased import prices make the Swedish GDP drop, while a share of the increased import prices pass on to the consumer prices.

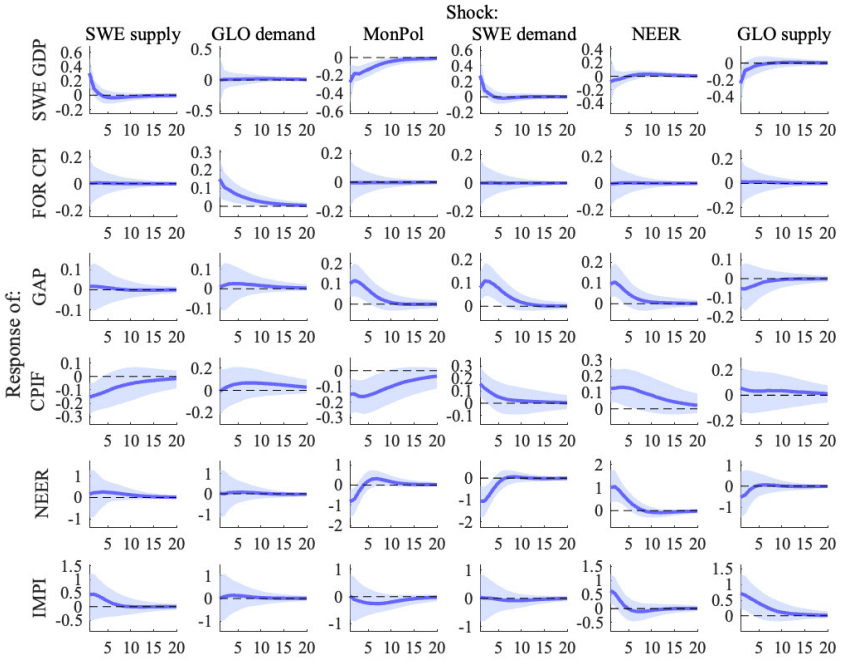

Figure A.2: Impulse responses, import price specification

A.3 Forecast error variance decomposition, import price specification

Figure A.3 presents the import price specification's FEVD. Exchange rate shocks explain exchange rate fluctuations to approximately 20 percent. Global shocks explain 28 percent, while domestic shocks explain the remaining 52 percent. This FEVD aligns with the first specification's FEVD. Global shocks explain a little more than 30 percent of the CPIF inflation's variance decomposition. The larger importance of global shocks to consumer price inflation than to the exchange rate aligns with the evidence presented in Section 3.3. Exchange rate shocks explain approximately 14 percent, while the remaining domestic shocks explain 52 percent.

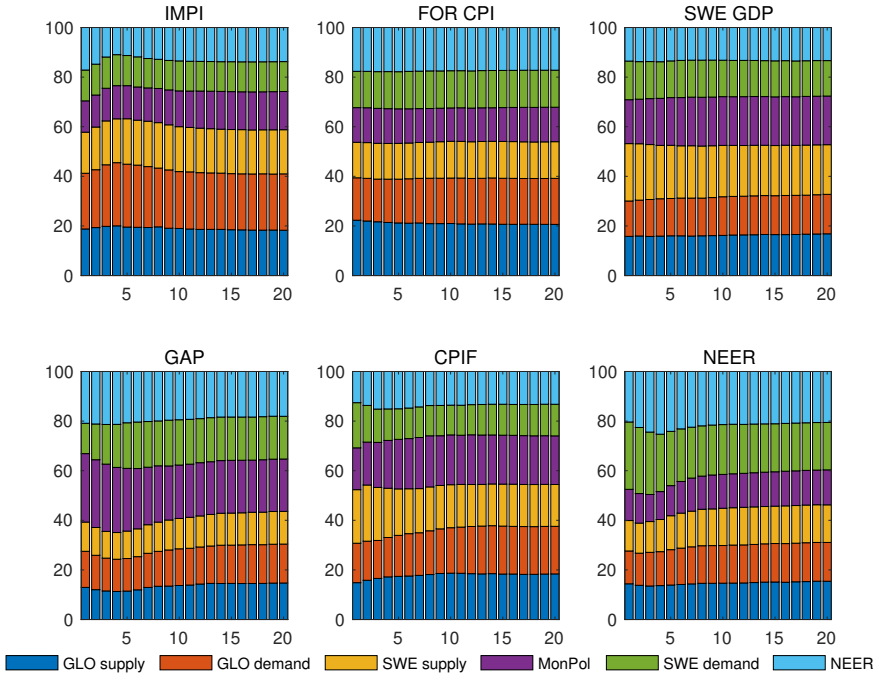

Figure A.3: Forecast error variance decomposition, import price specification

A.4 Historical decomposition, import price specification

The exchange rate's historical decomposition is presented in Figure A.4. Similar to the specification on consumer prices (see Figure 3), the most significant contributors to the exchange rate fluctuations are exchange rate shocks and Swedish demand shocks. In contrast to the first specification, the depreciation in 2022 is now more considerably explained by exchange rate shocks and, to a lesser extent, explained by monetary policy. Further, global demand shocks contribute more to the strengthened Swedish krona when import prices are included.

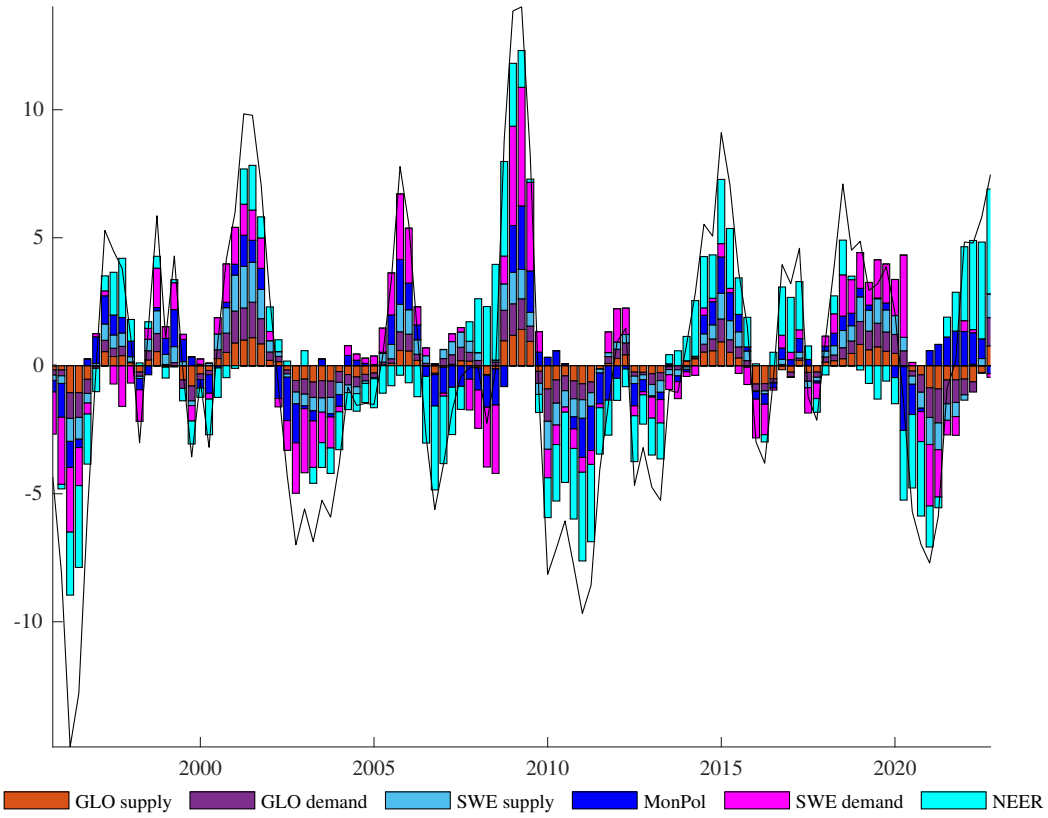

Figure A.4: Historical decomposition of the Swedish exchange rate, import price specification

The historical decomposition of consumer price inflation is shown in Figure A.5. Similar to the first specification (see Figure 4), monetary policy shocks explain a large share of the inflation. However, the magnitude has decreased slightly, and instead, exchange rate shocks and global shocks have gained importance. Similar to Figure 6, where the decomposition of import prices is presented, global shocks have recently increased their impact. Especially global supply shocks, which contain import prices, have been a significant driver behind consumer prices. The increased importance of the shock suggests that lately, the ERPT from import prices to consumer prices have been significant.

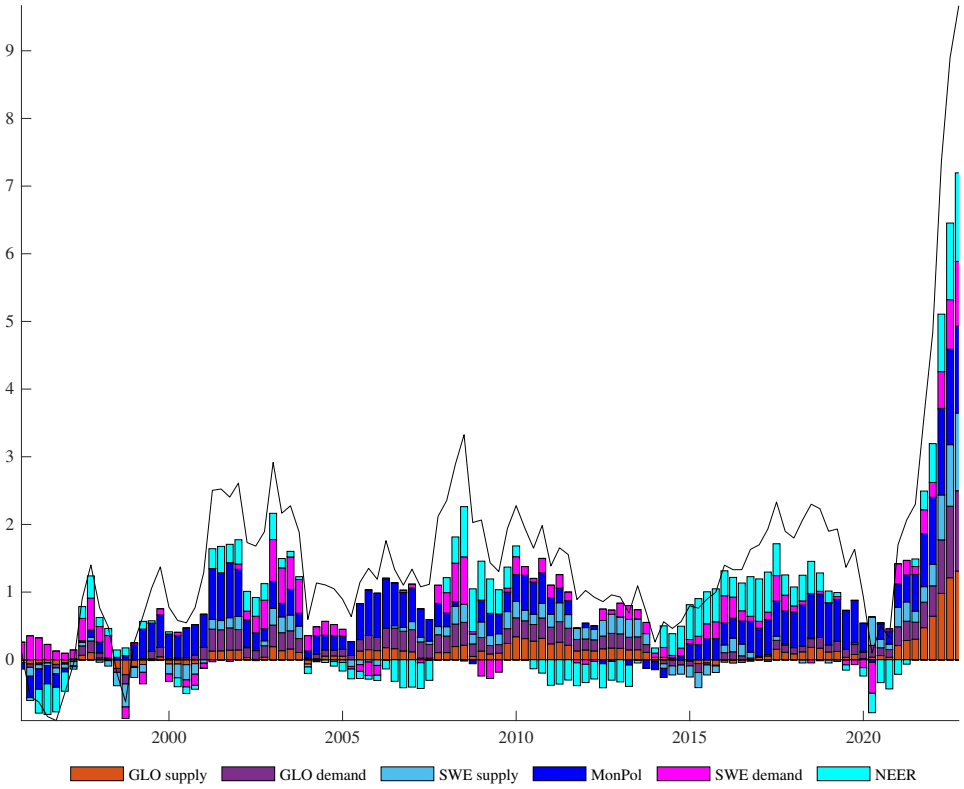

Figure A.5: Historical decomposition of the CPIF inflation, import price specification

A.5 Forecast error variance decomposition, frequency of price adjustment specification

Figure A.6 presents the FEVD for the frequency of price adjustment specification. Exchange rate shocks explain approximately 20 percent of the exchange rate fluctuations, global shocks explain 32 percent, and domestic shocks explain 48 percent. The frequency's FEVD has the following construction: exchange rate shocks explain 13 percent of the variance decomposition, global shocks explain 33 percent, and domestic shocks explain 54 percent. The importance of each type of shock individually is roughly evenly distributed: each shock explain between 13 and 18 percent.

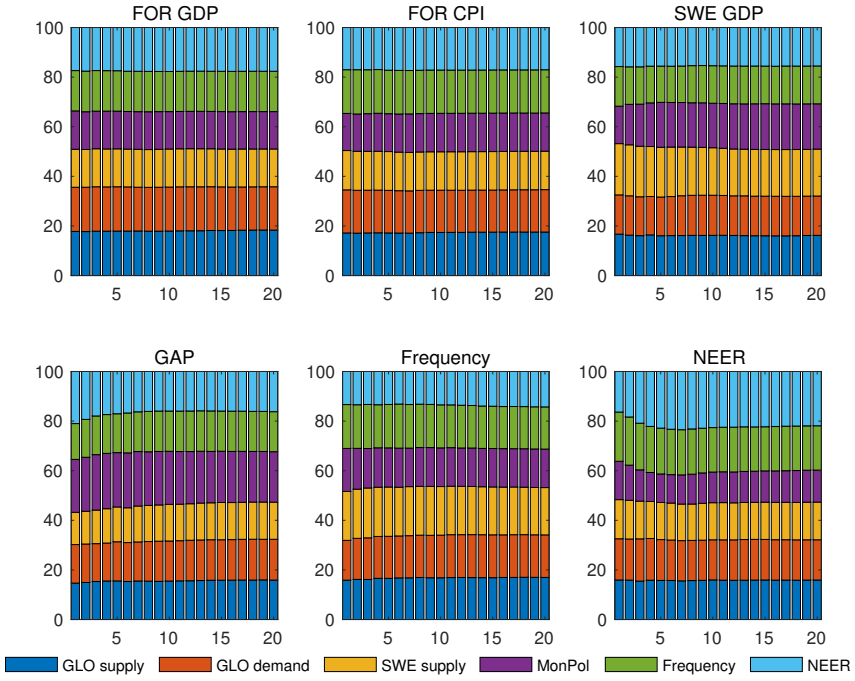

Figure A.6: Forecast error variance decomposition, frequency of price adjustment specification

B Appendix, figures

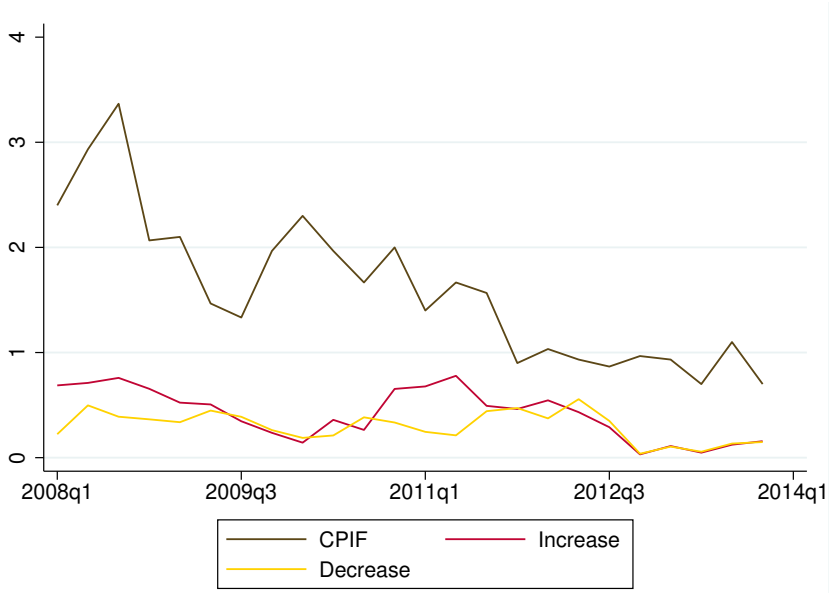

Figure B.1: Frequency of price adjustment increase, decrease & CPIF

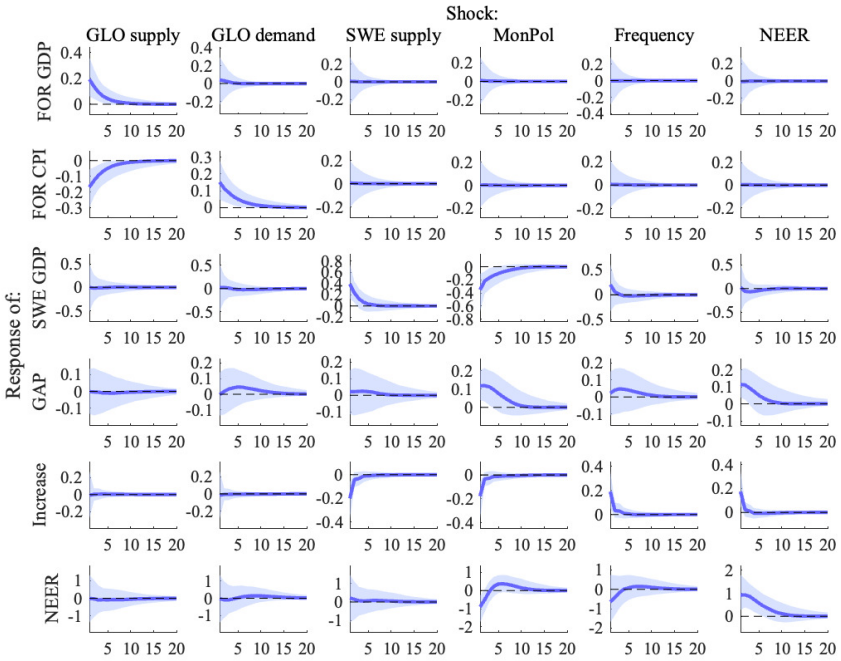

Figure B.2: Impulse responses, frequency of price adjustment increase

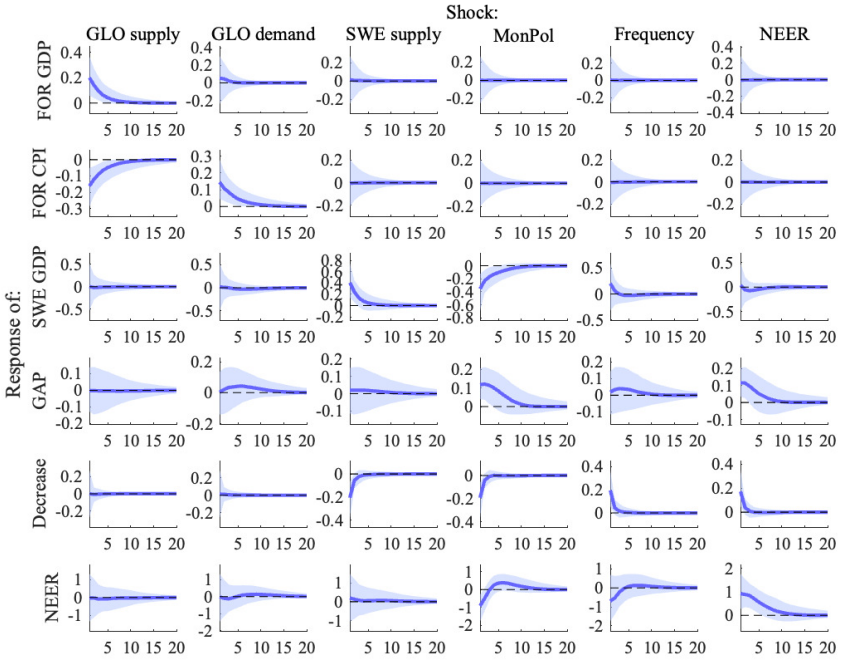

Figure B.3: Impulse responses, frequency of price adjustment decrease

C Appendix, robustness & variable description

C.1 Robustness

The lag structure is manipulated to test robustness. One can examine whether the results are impacted by changing the lag structure. Consequently, the model is estimated using one, three, and four lags. The FEVDs of my model using different numbers of lags are presented in Table C.1. There are no notable differences between the baseline specification where 2 lags are used (column 2 of Table C.1) compared to where 1, 3, or 4 lags are used (columns 3-5 of Table C.1).

Table C.1: Robustness Test

	Baseline, 2 lags	**1 lag**	**3 lags**	**4 lags**
Swedish Supply Shock	13.2 %	11.9 %	12.5 %	13.2 %
Swedish Demand Shock	24.8 %	24.1 %	24.0 %	23.4 %
Monetary Policy Shock	13.2 %	13.5 %	13.7 %	13.9 %
Exchange Rate Shock	20.2 %	21.3 %	21.4 %	20.8 %
Global Demand Shock	14.5 %	14.5 %	14.5 %	13.8 %
Global Supply Shock	14.1%	14.7 %	13.9 %	14.9 %

Further, the different specifications allow for evaluating the main findings in the baseline specification. Using different specifications tests the results' robustness with different data and restrictions.

Table C.2: Variable description

Variable	**Variable Name**	**Description**	**Source**
Swedish GDP	SWE GDP	Swedish GDP	Statistics Sweden
Swedish CPI	CPIF	Consumer Price Index with fixed interest rate	Statistics Sweden
Monetary policy	GAP	Swedish Central Bank's policy rate, de-trended using HP-filter	Sveriges Riksbank
Exchange rate	NEER	KIX-Index	Sveriges Riksbank
Foreign GDP	FOR GDP	Weighted average of Sweden's trading partners, using KIX-Index	OECD & Sveriges Riksbank
Foreign CPI	FOR CPI	Weighted average of Sweden's trading partners, using KIX-Index	OECD & Sveriges Riksbank
Import prices	IMPI	Import Price Index	Statistics Sweden
Frequency of price adjustment	Frequency	Frequency of Price Adjustment 2008-2013	Billion Prices Project Dataverse