Conditional exchange rate pass-through: evidence from Sweden*

Vesna Corbo† Paola Di Casola‡

Sveriges Riksbank Working Paper Series
No. 352

March 2018

Abstract

The pass-through from exchange rate changes to inflation differs depending on the underlying shock. This paper quantifies the conditional exchange rate pass-through (CERPT) to prices, i.e. the change in prices relative to that in the exchange rate following a certain exogenous shock, with a structural econometric approach using data for Sweden, a small economy that is very open to trade. We find that the pass-through to consumer prices following an exogenous exchange rate shock is rather small. Importantly, this shock is not the most important driver of exchange rate fluctuations, unlike what standard structural macroeconomic models would indicate. For Sweden, the CERPT is negative not only for domestic but also for global demand shocks. The estimated combination of shocks with positive and negative CERPT implies that the average pass-through to consumer prices is roughly zero.

Keywords: Exchange rate, pass-through, consumer prices, import prices, monetary policy, SVAR.

JEL classification: E31, E52, F31, F41.

---

*We thank Jonás Arias, Paolo Bonomolo, Jens Iversen, Jesper Lindé, Ulf Söderström, Karl Walentin and seminar participants at Sveriges Riksbank for useful comments. We are also grateful to Johan Löf for valuable advice on data choices. The opinions expressed in this article are the sole responsibility of the author and should not be interpreted as reflecting the views of Sveriges Riksbank.

†Sveriges Riksbank, SE–103 37 Stockholm, Sweden. E-mail: vesna.corbo@riksbank.se.

‡Sveriges Riksbank, SE–103 37 Stockholm, Sweden. E-mail: paola.dicasola@riksbank.se.

1 Introduction

The pass-through from exchange rate movements to prices varies depending on the shock that drives the change in the exchange rate. While we are used to thinking that an observed change in GDP, for example, could be driven by demand or productivity shocks implying opposite effects on inflation, we do not as frequently apply this type of reasoning to our analysis of the exchange rate. When analyzing exchange rate movements, there appears instead to be a general idea that exchange rates are driven primarily by their own shocks and that an appreciation of the exchange rate implies lower inflation. The magnitude of the price change is not infrequently quantified by some rule of thumb. A potential explanation behind this reasoning may be the well-established fact that our economic models often have a hard time explaining the observed exchange rate movements in the data.[1] This phenomenon has been dubbed the "exchange rate disconnect puzzle" by Obstfeld and Rogoff (2000), and refers to the weak relationship between the exchange rate and other macroeconomic variables, and many of our standard policy analysis models do assign a large share of the variation in the exchange rate to exogenous risk premium shocks.[2] This could reflect the fact that exchange rates are largely disconnected from the rest of the economy, but could also simply mirror the inability of the uncovered interest rate parity (UIP) condition to explain how exchange rates are determined in practice.[3] Resorting to a different class of models, we can shed some light on this question.

In this paper we estimate two structural VAR models with the purpose of studying the pass-through of exchange rate movements to final consumer and import prices in Sweden, conditional on the shock causing the variation in the exchange rate. Our interest is in the overall response of inflation that can be expected when observing a movement in the exchange rate, depending on the set of underlying shocks. This is a problem that policy makers, such as central banks, are repeatedly faced with. Sweden is a particularly interesting case of study, because it is a small economy that is very

[1]See Meese and Rogoff (1983b, 1983a) for early references showing that exchange rates forecasts from economic models could not outperform those of a simple random walk.

[2]The DSGE model used by the Swedish central bank (Sveriges Riksbank), Ramses, is one such example. See Adolfson et al. (2013) for a description of the current vintage of this model.

[3]In small open economy DSGE models such as Ramses II, ToTEM (Murchison and Rennison, 2006) and KITT (Beneš et al., 2009), the exchange rate is usually determined by some UIP condition, modified to allow for (at least) some exogenous movements to the exchange rate, reflecting the risk premium required by investors for holding domestic assets. However, there is a large body of cross-country empirical literature showing that the UIP condition does not hold in the data – see Engel (2014) for a literature review. The implications of this for estimation of open-economy DSGE models is discussed in Justiniano and Preston (2010).

open to trade with the rest of the world and its central bank, Sveriges Riksbank, has had an inflation target since 1995. The average share of imports and exports over GDP – the index of trade openness – for the Swedish economy has equaled 82 percent over the last two decades. This signals a very large trading sector, even with respect to other small open economies of the developed world with similar inflation targeting central banks – the corresponding number is 54 percent for the United Kingdom, 59 percent for New Zealand, 69 percent for Canada, and 70 percent for Norway.[4] The effect of exchange rate movements are thus of major importance for economic activity, through monetary policy as well as international trade.

To take an example, say that we observe an exchange rate appreciation at a certain point in time. What are then the implications for the economy in general and monetary policy in particular? If the observed exchange rate appreciation was brought about by an exogenous exchange rate shock, such as a change in the risk premia required by investors for holding assets denominated in foreign currency, we can expect import prices to drop, all else equal. This, in turn, exerts a downward pressure on aggregate consumer prices – the larger the higher the share of imports in the aggregate – which may be further strengthened by a possible substitution away from domestically produced goods towards imported goods. Assuming that the central bank is an inflation targeter, the downward pressure on aggregate inflation then calls for a looser monetary policy. If, on the other hand, the observed exchange rate appreciation is caused by a positive demand shock, the net effect on inflation is less clear. The same downward pressure on aggregate inflation from lower import prices is still there. But now, there is also an upward pressure on inflation coming from the increased demand for all goods. If the latter effect is dominating, we can expect to see an increase in inflation as well as real economic growth at the same time that we observe an exchange rate appreciation. This would call for a tighter monetary policy, to offset the inflationary pressures from the increased demand. The different causes of the exchange rate movement will thus have different implications for the economy and for monetary policy, pointing to the importance of understanding the forces behind the currency fluctuations we observe. Moreover, the specific monetary policy regime is relevant for the results, as it will affect the ultimate response of inflation as well as the exchange rate and thus also the perceived pass-through.[5]

[4]All numbers correspond to averages of trade (imports and exports) shares of GDP from OECD data over the period 1995-2016.

[5]See Gagnon and Ihrig (2004) for evidence of monetary policy parameters affecting the exchange rate pass-through, arguing in particular for the importance of the degree of inflation stabilization. A higher weight on real activity relative to inflation will, all else equal, generate a higher pass-

As discussed in Campa and Goldberg (2005), there are other factors such as the choice of invoice currencies in trade and the degree of openness which are relevant in explaining a country's pass-through. Here, we are not interested in comparing pass-through across countries but are rather focused on the way pass-through differs depending on the underlying cause of the exchange rate movement. We study the case of Sweden as it is a very open economy, thus giving us the right prerequisites to identify this conditional pass-through, with a longstanding stable inflation-targeting regime, making our results relevant also for other inflation-targeting countries.

To assess the degree of pass-through of exchange rate movements to prices, we use two alternative models and identification strategies, with short-run, long-run and sign restrictions. We present first our preferred specification for the assessment of exchange rate pass-through to consumer prices, followed by an alternative specification which also enables us to discuss pass-through to import prices. This also allows us to shed some light on the sensitivity of our results to the specific identifying assumptions used. We include six macroeconomic variables in our model, identifying six structural shocks – four domestic and two global. Having identified the shocks, we can use shock decompositions to assess the degree to which the exchange rate is driven by its own shock and by other shocks to the economy, respectively. We compute the pass-through to prices following each of the identified shocks – what we will hereafter refer to as the conditional exchange rate pass-through (CERPT) – as well as a measure of average pass-through to prices.

We find that the lion's share of exchange rate fluctuations is explained by shocks other than the shock to the exchange rate itself. The exogenous exchange rate shock always features a small CERPT and explains at most some 20 percent of the fluctuations in the effective exchange rate. This is an important finding to highlight the limitations of DSGE models and traditional assessments of exchange rate pass-through based on estimates of exogenous movements in the exchange rate. Moreover, we find that the exchange rate pass-through varies substantially by shock. The CERPT to Swedish consumer prices may be as high as $10-15$ percent, following monetary policy or global supply shocks, and around 5 percent following the exogenous exchange rate shock. The CERPT is negative when the economy is hit by domestic and foreign demand shocks. In other words, a 1 percent appreciation of the exchange rate brought

through to inflation following an exogenous exchange rate shock in a DSGE model such as Adolfson et al. (2013). The effects on pass-through following other shocks vary, as both the inflation and the exchange rate responses will be affected by the differing monetary policy rules. Clearly, a monetary policy rule focused on limiting exchange rate movements will also results in generally different degrees of pass-through compared to an inflation targeting rule.

about by stronger demand, in Sweden or abroad, is accompanied by an increase rather than decrease in consumer prices by 5 or 20 percent (depending on the origin of the shock) in the long run and even higher in the short run.[6] After demand shocks, the upward pressure on prices stemming from increased demand thus dominates the effect of the exchange rate movements on producers' costs. While a negative CERPT is found also in the other studies following the domestic demand shock, as we will discuss further below, a feature that is specific to our studies of Sweden is that the CERPT is negative even after *global* demand shocks. Foreign shocks are very important drivers of the Swedish economy, as pointed out in Lindé (2003) and Bonomolo et al. (2018). Hence, knowing that the foreign demand shock features a negative exchange rate pass-through has important implications for the expected movements of inflation and consequently for the conduct of monetary policy.

Our paper is related to a large literature on the exchange rate pass-through. A few examples are Campa and Goldberg (2005), Burstein and Gopinath (2014) and Gopinath et al. (2010), but there are many more important contributions to this field. There are, however, few studies in the literature that focus explicitly on the underlying drivers of exchange rate fluctuations and highlight a different pass-through depending on the shock hitting the economy, outside of DSGE models. Shambaugh (2008) uses a structural VAR model identified with long-run restrictions for a set of 16 countries to derive the ERPT to consumer and import prices. In this sense, the paper was an important first step in improving our understanding of shock-dependent ERPT. The closest paper to ours is Forbes et al. (2015), where a structural VAR model is estimated on UK data relying on sign, short-run and long-run identification restrictions derived from a theoretical open-economy model. This paper is able to identify more shocks (four domestic shocks and two global shocks) than Shambaugh (2008) and to focus also on monetary policy. A similar approach to Forbes et al. (2015) has been used to estimate the ERPT by shock for the Euro area and four member states (Germany, France, Italy, and Spain) by Comunale and Kunovac (2017). Forbes et al. (2017) modified the original approach from Forbes et al. (2015) in order to estimate the ERPT by shock for 26 developed and emerging economies and study its variation across time and economic structure, covering also the case of Sweden. Our contribution to this growing literature is both methodological and quantitative. On the methodological side, we provide a different identification for the structural VAR

[6]Note that we here refer to deviations from long-term trends, and so our results regarding the price changes and levels should be interpreted as deviations from the average inflation in our sample. Our exact treatment of the data series is described further in Section 2 below.

model used to derive the conditional exchange rate pass-through compared to previous studies. By including both foreign prices and quantities, we are able to better asses the role of foreign demand and supply shocks, even with minimum identifying restrictions, while still being able to compare them to the exogenous exchange rate shock. Instead, the specification proposed in Forbes et al. (2015) and used in Comunale and Kunovac (2017) contain information only about foreign prices. On the quantitative side, the very high openness of the Swedish economy to trade compared to other inflation targeting economies and the large importance of exchange rate movements for the economy makes Sweden a particularly interesting case to study. The policy implications from our study are also relevant for other small open economies with inflation-targeting central banks.

The rest of the paper is organized as follows. Section 2 describes the data used and the estimation methodology, and Section 3 provides a definition of conditional exchange rate pass-through. Section 4 discusses our benchmark model for the estimation of CERPT to consumer prices, and Section 5 presents an alternative identification strategy which allows us to also discuss CERPT to import prices. Section 6 shows the results of the data sensitivity analysis and Section 7 concludes.

2 Data and estimation

We estimate a six-variable VAR model, allowing us to identify a total of six structural shocks – four domestic and two global. We do this for two different specifications: our preferred one for the assessment of exchange rate pass-through to consumer prices, which includes foreign prices and quantities for the identification of global shocks, and an alternative specification which relies on data to import prices and thus allows us to also study the pass-through to those. The identifying assumptions are discussed in detail in relation to each respective model in Sections 4 and 5 below.

We run our estimations on data for Sweden covering, roughly, the inflation targeting period starting in 1995 until present. All series are quarterly and, as some series are included in first differences, our sample covers 1995q2 through 2017q2. The series included in our benchmark specification are Swedish GDP, consumer prices, policy rate and exchange rate, as well as foreign consumer prices and foreign GDP. In the alternative model, the foreign GDP series is replaced with import prices. All series but the policy rate are measured in terms of quarterly log differences. Figures of all the data series are reported in Appendix A.

Consumer prices are measured as the rate of inflation of CPIF, that is the consumer price index inflation with the mortgage rates held fixed. This is the standard measure used in the Riksbank's macroeconomic models, as changes to household mortgage rates have a direct effect on CPI via the component that measures households' interest expenses for owner-occupied housing. When interest rates drop, for example, CPI inflation is pushed down - an effect that can be sizeable in periods of major changes to monetary policy. Thus, the CPI does not provide a fair picture of inflationary pressures in periods with substantial interest rates changes, as during our sample. The CPIF has been the Riksbank's operational target variable for several years and as of September 2017 it is the formal inflation target variable for monetary policy. The monetary policy measure used is the gap between the repo rate, i.e. the Swedish policy rate, and a measure of a time-varying interest rate trend. Over our sample, the repo rate has consistently trended downwards, in a way that mirrors the medium- to long-term movements in interest rates in other advanced economies. As the trend is not specific to Swedish data, we treat it as an exogenous change in the global (real) rate, and thus remove it prior to our estimation. This approach is chosen also in Forbes et al. (2015) (based on UK data), where the policy rate is de-trended in order to adjust for the downward trend in UK interest rates during the relevant sample period. The time-varying interest rate trend we use is estimated in Strid and Bonomolo (forthcoming). They model medium- to long-term interest rate movements in the Riksbank's main DSGE model Ramses, assuming that they are driven by factors exogenous to the model affecting the global real rate, and refer to the measure as the neutral rate. The specific model of the neutral rate itself is inspired by the approach in Laubach and Williams (2003). We note also that the repo rate does not fully capture the monetary policy conducted since 2015, when the Riksbank started using asset purchases to make monetary policy more expansionary, in addition to the conventional interest rate tool. For this reason, we report results from a sensitivity analysis in Section 6, using a measure of monetary policy that contains also the effects of asset purchases – the shadow interest rate. The exchange rate is the nominal effective exchange rate index, produced using KIX weights.[7] The index is defined so that an increase implies a depreciation and a decrease an appreciation of the Swedish Krona. Foreign consumer prices and foreign GDP are measured as weighted averages of Sweden's main trading partners, using the KIX weights of the Krona

[7] KIX refers to an aggregate of countries that are important for Sweden's international transactions, in terms of imports, exports and third-country effects. The Euro area has the greatest weight, around 46 percent. For details on the construction of the index, see http://www.riksbank.se/en/Interest-and-exchange-rates/Explanation-of-the-series/Exchange-rate-index-currency-indices/.

index. We refer to them as KIX-CPI and KIX-GDP. In our second specification, KIX-CPI represents a proxy for global export price inflation. As our measure of import prices, we use the import price index for total imports of goods and services produced by Statistics Sweden – IMPI. For sensitivity analysis, in Section 6 we repeat our analysis with an additional measure, the import price deflator, that is obtained from data on imports in current and constant prices from the National Accounts.

We estimate the VAR models in first differences with 2 lags using Bayesian methods. We use the methodology laid out in Villani (2009), hence the VAR model is written in deviation from the steady state. To impose sign and zero restrictions on the Bayesian VAR we follow the algorithm proposed in Arias et al. (2014), with Minnesota priors.[8] Arias et al. (2014) provide an algorithm that allows to impose zero and sign restrictions on Bayesian VAR models by using priors that are agnostic or conditionally agnostic. Other algorithms, such as the one used in Forbes et al. (2015), have the drawback that the priors may affect the identification. The reported results are based on 2000 draws, after we have discarded the initial 200 ones.

3 Definition of conditional exchange rate pass-through

We define the conditional exchange rate pass-through as the ratio of the impulse response of prices to that of the exchange rate, for each shock s. The increase in prices over a k-period horizon produced by an exogenous shock s, hitting the economy and generating a depreciation in the exchange rate, is given by

$$CERPT_{s,k} = \frac{\sum_{j=0}^{k} \Delta Price\,Index_j}{\sum_{j=0}^{k} \Delta NEER_j}, \tag{1}$$

where $CERPT$ denotes the conditional exchange rate pass-through and $NEER$ denotes the nominal effective exchange rate. As the measure is cumulative, its value reports the total effect over k periods of a depreciation in the exchange rate. It thus reflects the full dynamics of prices associated with exchange rate changes. Note that the pass-through defined in this way may be negative. This would be the case if prices decreased, despite the fact that the exchange rate had depreciated.

[8] We set the hyperparameter representing the tightness of our prior on own lags as $\lambda_1 = 0.2$, the one about cross-equations as $\lambda_2 = 0.5$, the one about lag decay as $\lambda_3 = 1$ and, finally, the one about exogeneous variables as $\lambda_4 = 0.01$, due to the assumption of a small open economy.

4 CERPT to Swedish consumer prices – benchmark model

In this section, we focus on our preferred specification for assessing the CERPT to Swedish consumer prices. In the section that follows, we look at an alterative specification which also allows us to study the CERPT to Swedish import prices.

We begin by discussing the identifying assumptions that underlie our model estimation, before reporting the results. We next discuss the impulse response functions to the six identified shocks and then we disentangle how much of the fluctuations in the nominal exchange rate across time that are due to each shock through forecast error variance decompositions. We then look at historical decompositions for the exchange rate and the inflation rate. Finally, we compute the CERPT to consumer prices for each shock, as well as an average measure based on the importance of each shock in driving the fluctuations in the exchange rate.

4.1 Identification

Using the series described in Section 2, we identify the following six structural shocks: shocks to Swedish and global demand, shocks to Swedish and global supply, a Swedish monetary policy shock, and a shock to the nominal exchange rate. Our identification is based on zero short-run and long-run restrictions, as well as sign restrictions.

The restrictions we use are summarized in Table 1. As Sweden is a small open economy, of a size negligible to the global economy, we assume that Swedish domestic shocks can have no effect on global variables. This is a standard assumption for economies which are small enough compared to the world market that their economic developments have no influence on global quantities or prices. Swedish shocks are thus restricted to have zero short-run effects on foreign GDP and foreign CPI. In addition, the foreign variables are defined as exogenous, meaning that the dynamic effect of the Swedish shocks on the foreign variables is restricted to be null. Hence, we do not need to impose any zero long-run restrictions from the Swedish shocks to the foreign variables. The identification of the specific domestic shocks is then based on sign restrictions. These are generally imposed on impact, that is in the quarter when the shock hits (unless otherwise mentioned).

We assume that only supply shocks are allowed to affect the level of GDP in the long run, which corresponds to imposing zero long-run restrictions on GDP for all of the remaining shocks. This identification restriction is a standard one, going back to

Table 1: Identifying restrictions for the benchmark model

	Exog ER shock	SWE demand shock	SWE mon pol shock	SWE supply shock	Global demand shock	Global supply shock
	Short-run restrictions					
Δ SWE nom ER	+	-	-			
Δ SWE CPI	+	+	-	-		
SWE int rate	+	+	+			
Relative GDP		+	-	+		
Δ KIX CPI	0	0	0	0	+	-
Δ KIX GDP	0	0	0	0		+
	Long-run restrictions					
Δ SWE nom ER						
Δ SWE CPI						
SWE int rate						
Relative GDP						
Δ KIX CPI						
Δ KIX GDP					0	

Note: The signs on the diagonal are included in the table for clarity, and are only there for normalization purposes. Only for the global supply shock, the (-) sign restriction is imposed for 2 quarters following the shock.

the work by Blanchard and Quah (1989). Note, however, that we include two GDP series in the model – one for Sweden and one for the foreign economy – and that for each GDP series included, we need zero long-run restrictions to allow only supply shocks to affect GDP in the long run. Having two GDP series would generally force us to double the zero long-run restrictions, which is not achievable within our setup. In order to reduce the number of restrictions for the identification of the shocks, we replace Swedish GDP with relative Swedish GDP, measured as the quarterly log difference of the two rescaled series. In this way we impose co-integration between Swedish and foreign GDP, implying that the two series are assumed to co-move in the long run (see Figure A.2 in Appendix A). We then only need to impose zero long-run restrictions for the foreign GDP. Note that this means that only the foreign supply shock is allowed to have permanent effects on Swedish GDP. This assumption is in line with assuming that permanent technology shocks are always global and that country-specific technology shocks are stationary. It is common in structural models, such as Adolfson et al. (2007) and Christiano et al. (2011). In other words, we assume that there are technological spillovers across countries such that the long-run movements in technology are global and that any country-specific deviations from those are temporary. Assuming otherwise, i.e. allowing an economy to grow at a faster or slower pace than the rest of the world in the long run, would imply that the economy would either disappear or become as large as the world, and is thus theoretically implausible. In a restricted sample as ours, however, growth rates may differ across economies. This turns out to be the case in our sample. In order to account for this difference in growth rates between Sweden and the foreign economies, we introduce a quadratic trend at the steady state, that is estimated together with the other parameters. As we are primarily interested in short to medium-term fluctuations, we do not analyze the reasons behind this trend further.

Moving on to the sign restrictions, the domestic supply shock is assumed to move GDP and Swedish consumer price inflation in opposite directions. The domestic demand shock is assumed to move GDP and Swedish consumer price inflation in the same direction. In addition, monetary policy is assumed to respond with an interest rate increase to a demand shock that has a positive impact on GDP and inflation, while the exchange rate is assumed to appreciate.[9] A monetary policy shock implying an increase in the interest rate is assumed to have a negative effect on GDP and Swedish consumer price inflation, and to bring about an appreciation in the exchange rate.

The shock to the nominal exchange rate, finally, is restricted to cause an increase in Swedish consumer price inflation when the exchange rate depreciates. Monetary policy is assumed to react by increasing the interest rate in response. We think of this shock as comparable to a risk premium shock to the UIP condition in a DSGE model as in, for example, Adolfson et al. (2007) and Christiano et al. (2011). As discussed in Itskhoki and Mukhin (2017), this shock can be interpreted as a financial shock and may originate from a number of different foundations. For example, it could

[9]We have tried the alternative identifying assumptions that the interest rate response should be positive following demand shocks only on average over the first year, rather than on impact. Based on standard theory of exchange rate determination, the UIP condition would then imply that the same identifying assumption should be imposed also for the exchange rate. Relaxing the restrictions on the interest rate and the exchange rate following demand shocks in this way had a very small impact on our results. Almost the entire distribution of the impulse response functions for these two variables had the expected sign already on impact, and all other results of our estimations remained unchanged.
Similarly, we have replaced the restriction on inflation following monetary policy shocks to an average over the first year rather than on impact, to allow for the possibility that some monetary policy shocks may occur late in the observed quarter and that inflation, in the presence of price stickiness, may respond with a lag. Our results were again largely unaltered.

capture shocks to the risk-bearing capacity of the financial sector, or deviations from full-information rational expectations in incomplete information models. It could also capture noise trader shocks in a model with trade in international assets going through risk-averse intermediaries, which require compensation for taking on currency risk. All of these interpretations would have the same implications for the UIP condition in a general equilibrium model, and are thus undistinguishable within that class of models.[10] Note that this shock is domestic, in our model as in standard small-open economy DSGE models, and is not allowed to have any effects on foreign variables as such. It is thus a financial or risk shock specific to Sweden and the Swedish Krona, and not a shock affecting financial markets globally. It is possible that some global financial shocks could have effects on the Krona over and above those going through trade channels, and that one should interpret also those as shocks to the exchange rate.[11] However, it is not possible to distinguish those shocks from the global temporary/demand shocks within our model. We thus bare in mind that part of the global demand shock contribution to exchange rate fluctuations may be capturing global exchange rate shocks when interpreting our results.

Regarding the global shocks, we assume that the global supply shock is allowed to affect the GDP level in the long run, while the global demand shock is not. The idea is that only shocks to technology have a permanent impact on GDP, while all other shocks are transitory, in line with what we have discussed above in relation to the domestic shock identification. In order to make sure that we are indeed capturing shocks that are related to technology, rather than very persistent demand shocks, we impose that the impact effect on prices should be negative for the first 2 quarters when the shock to GDP is positive.[12] In other words, the assumption is that the effects on prices and quantities are of opposite signs. We do not impose more restrictions on the global shocks, beyond what is needed to disentangle demand from supply shocks, to let the data speak for itself to the highest degree possible. Our model does not include a measure of the foreign interest rate, and thus we do not identify a foreign

[10]See Itskhoki and Mukhin (2017) for further details and for references to studies exploring each of the listed interpretations.

[11]Moreover, as we are using the effective exchange rate, it may also be the case that an exchange rate shock to the EUR-USD exchange rate, for example, has an effect on the effective Krona exchange rate. This would be a pure exchange rate shock, but not a shock particular to the Krona. It would then likely be captured by the temporary global shock in our model, rather than the exchange rate shock.

[12]Note that the price response of KIX CPI is normalized to be positive following the shock to global supply, due to the ordering of the variables in our model. In other words, all the elements on the diagonal of the upper matrix in Table 3 are set to a plus by assumption, and thus the restriction we need to impose on GDP is negative.

monetary policy shock, for three main reasons. First, we know from the earlier VAR studies on Swedish data that it is hard to identify foreign monetary policy shocks in practice.[13] Second, the identification of generalized demand shocks in Bonomolo et al. (2018) indicates that foreign monetary policy shocks play a rather small role in driving the Swedish macro variables, compared to the other global shocks. The third reason, potentially related to the first, is that unconventional measures have for some time now been a crucial element of the monetary policy conducted in some of Sweden's main trading partners. In the Euro Area, US and UK, which compose the major part of the foreign policy rate aggregate, interest rates have shown little variation during the last decade of our sample. At the same time, however, there is no consensus on what other measures of monetary policy stance that would be optimal to use.[14] We thus stick to a smaller model, with only two global variables, and note that foreign monetary policy shocks will be captured by the foreign demand shock in our setting.

Finally, note that we are agnostic about how the exchange rate should respond to the two global shocks. The response should in theory depend on the extent to which movements in the global economy spill over to the Swedish economy and what the responses of the Swedish interest rates relative to foreign interest rates are, something that we do not wish to lay a prior on. Similarly, not having made any assumption on what the monetary policy response following the domestic supply shock should be, we leave the exchange rate unrestricted in response to this shock as well.

4.2 Impulse response functions

The impulse response functions are reported in Figures B.1 to B.6. We note that they have been rescaled so as to generate a one percent depreciation of the Swedish Krona after 4 quarters. In addition to our median responses, we report the 68 and 90 percent probability bands. Since the calculation of the CERPT requires the impulse responses of prices and exchange rate in levels (see equation (1)), we report the IRFs with probability bands also for the cumulated price indexes and the cumulated change in the exchange rate and in GDP. We will focus the discussion on the responses of the exchange rate and the price indexes.

We start by looking at the IRFs to an exogenous exchange rate shock in Figure

[13] We discuss other VAR studies on Swedish data in the next section.

[14] Admittedly, measurement problems related to unconventional monetary policy measures are of some relevance also in Swedish data. However, for Sweden, this issue is restricted to a much shorter period at the end of our sample and sensitivity analysis relying on a shadow rate measure indicates that it is of minor importance.

B.1. In line with the instantaneous sign restrictions, after the depreciation of the Krona, consumer prices increase and the repo rate goes up. If anything, the Swedish GDP goes down on impact but the response goes to zero in the long run in line with the assumed co-integration with the foreign GDP. The 68 percent probability bands include zero on impact, but become negative in the second year after the shock hits.

Next, we move to the Swedish demand shock in Figure B.2. We look at a negative demand shock, as this is what generates an exchange rate depreciation. A shock that pushes down GDP and CPIF depreciates the Krona and causes a decrease in the repo, in line with the instantaneous sign restrictions. The CERPT, as defined in Section 3, is thus negative. The response of inflation is short-lived and price levels are permanently shifted down almost immediately. The 90 percent probability bands of the price level response include zero in the longer run, and we thus note that there is some uncertainty around the sign of the CERPT in the long run following domestic demand shocks.

A negative Swedish monetary policy shock, shown in Figure B.3, induces a depreciation of the Krona and an increase in consumer prices and GDP, in line with the sign restrictions. The size of the on-impact response of consumer prices in our estimation is roughly in line with other estimates of responses to monetary policy shocks for Sweden (see Villani and Warne (2003) and Lindé et al. (2009)). The responses of price and exchange rate levels are positive throughout our studied horizon.

A positive Swedish supply shock, shown in Figure B.4, induces an increase in GDP and a drop in CPIF, in line with the imposed sign restrictions. These are accompanied by an increase in the repo rate and a weakening Krona, at least judging by the median response. Despite not observing foreign interest rates, the assumption that Sweden is a small open economy and that shocks originating in Sweden therefore do not affect the rest of the world, allows us to evaluate the UIP condition as movements in the interest rate differential are driven by Swedish interest rate movements only. The increase in the repo rate, together with the foreign-exogeneity assumption, should generate an appreciation of the Krona according to the UIP condition. This is not the case in our model following domestic supply shocks, where the movements in the exchange rate in fact go in the opposite direction.[15] The 68 percent probability intervals of both the repo rate and the Krona responses include zero, however, so we interpret the results with some caution.

We now turn to the global shocks. A negative global demand shock, shown in Fig-

[15] For the monetary policy and the demand shocks, the sign of the exchange rate response was imposed and thus of the expected sign as implied by the UIP condition.

ure B.5, drives down foreign prices and GDP, as well as Swedish consumer prices and Swedish GDP. It brings about a drop in the repo and a weakening of the Krona. Thus, as for the Swedish demand shock, we observe lower prices together with a weaker exchange rate. Following the global demand shock, moreover, the price response is clearly negative at all horizons. Note that, as the model does not include the foreign interest rate, it is not clear what response of the exchange rate we should expect. As global variables are no longer restricted as in the case of Swedish shocks, we cannot draw conclusions regarding the interest rate differential based on the Swedish interest rate only. From Bonomolo et al. (2018), which studies the Swedish economy through the lens of BVAR models including foreign quantities and interest rates, we know that the Swedish krona tends to strengthen (weaken) when the foreign business cycle is strong (weak) and that it does not always move in line with the UIP condition. The results from our model are in line with these findings.

A negative global supply shock, finally, shown in Figure B.6, generates a fall in foreign GDP and increase in foreign prices, in line with the instantaneous sign restrictions. This shock generates a drop in Swedish GDP and an increase in Swedish consumer prices, and the repo increases during the first year or so to counteract the rise in inflation before turning negative. The Krona again depreciates, in line with what was described for the global demand shock above.

4.3 Decompositions

Having identified the six shocks discussed in the previous section, we can now move on to disentangling their relative importance in explaining the fluctuations in the nominal exchange rate and prices across time. We first present the forecast error variance decomposition of the exchange rate. The rest of the section is then devoted to discussing the historical decompositions of the exchange rate and the inflation rate.[16]

Table 2: Forecast error variance decomposition (FEVD) of the the nominal effective exchange rate for the benchmark model

	Exog ER	Swe D	Swe MP	Swe S	Global D	Global S
NEER	22	32	13	13	9	11

Note: The numbers represent percentages of the forecast error variance due to each shock.

[16]For historical decompositions of all remaining variables, see Appendix C.

Table 2 presents the share of the exchange rate forecast error variance that is explained by each of the six identified shocks at the 8-quarter horizon.[17] The exogenous exchange rate shock explains 22 percent, while the remaining 78 percent is due to the other shocks. In our specification, 20 percent of the Swedish Krona movements are explained by global shocks and 58 percent is due to the three remaining domestic shocks. The domestic demand shock features the highest share, equal to 32 percent. It is interesting that the exogenous exchange rate shock, which is the one responsible for most of the exchange rate variations in small open economy DSGE models, seems to account for a rather limited share of exchange rate movements.[18] These results shed some light on the limitations of the analysis of exchange rates in that type of models.

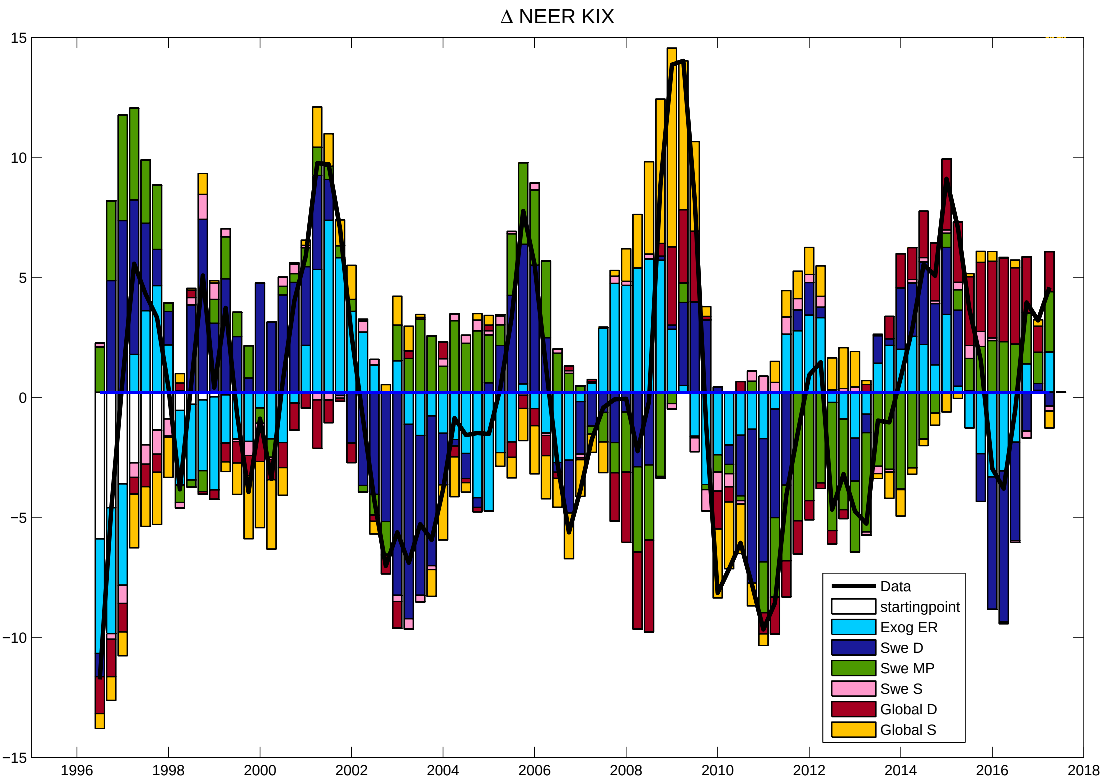

Figure 1: Historical decomposition of the the nominal effective Krona exchange rate, year-on-year changes

[17]The FEVD shows little variation over horizons, why we only report these numbers.

[18]Even if it were the case that the global demand shock partly captured financial global shocks which should be interpreted as exchange rate shocks, the variance share explained by exchange rate shocks would most likely not exceed one quarter.

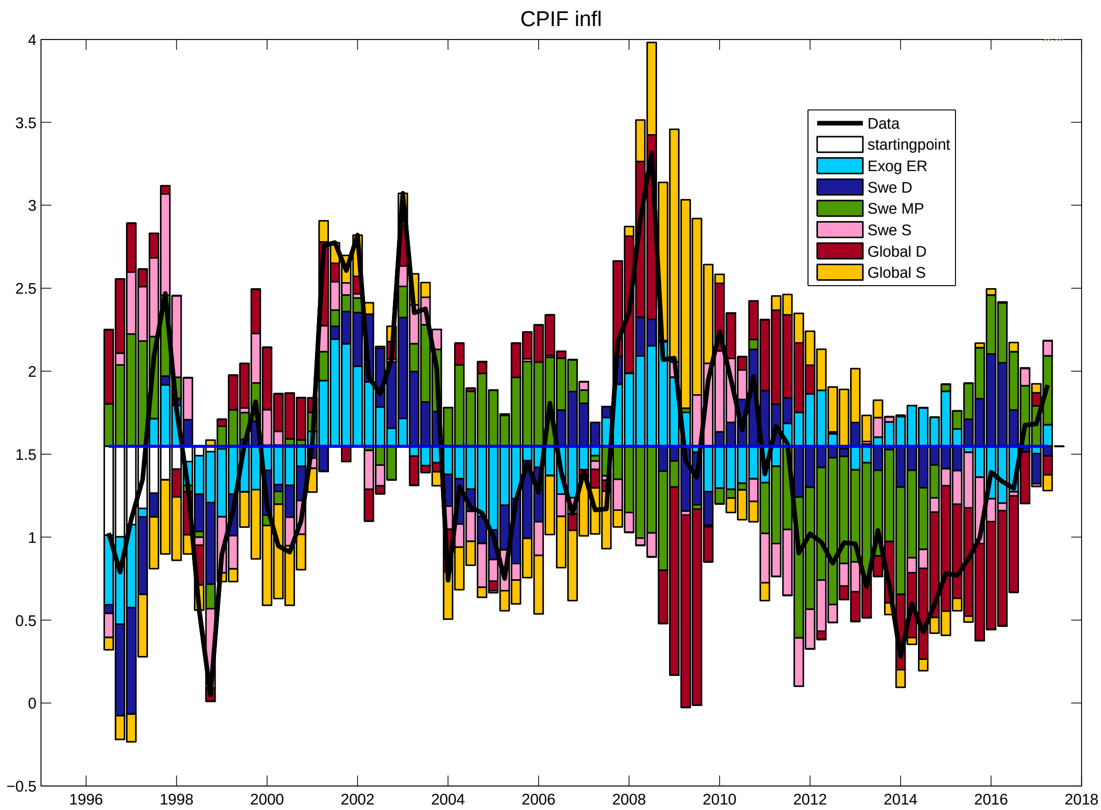

Figure 2: Historical decomposition of the the CPIF inflation, year-on-year changes

Figure 1 shows the role of each shock for the deviations across time of the annual change of NEER from its historical average. As suggested by the FEVD of the Swedish Krona in Table 2, Swedish monetary policy shocks and demand shocks have been important for the exchange rate developments, in addition to the exchange rate shock. Focusing on the period since the recent financial crisis, the importance of global shocks seems also to have increased. During the latest financial crisis, the Krona underwent the largest depreciation of the last two decades, that was to a large extent due to negative global shocks and exogenous exchange rate shocks. This is in line with other studies that analyze the performance of the Swedish economy during the recent global financial crisis. For example, Hopkins et al. (2009) show that the sizeable deterioration of Swedish financial conditions was mostly due to global factors, especially developments in foreign financial markets. The financial crisis was mostly an imported phenomenon for a small open economy like Sweden. We note that, in contrast to that, the results for Sweden in Forbes et al. (2017) indicate that the development during the crisis was largely due to Swedish demand shocks.[19] However, the scope for comparison is limited, since the authors use a different measure for inflation and the exogenous exchange rate shock is omitted.

From 2013, another sizeable depreciation started, this time driven largely by diminishing negative contributions from monetary policy shocks, but also the weak global and domestic demand and, to some extent, the exogenous exchange rate shocks contributed. Restrictive monetary policy had a strengthening effect on the Krona between 2011 and 2014, before reversing sign towards the end of our sample. Finally, from Figure 1 we can see that the most recent depreciation was due to disappearing local demand shocks in combination with a more persistent contribution from negative global demand shocks and monetary policy shocks.

Moving on to the decomposition of the CPIF inflation in Figure 2, it is clear that global shocks have been important drivers alongside monetary policy shock. We note that the monetary policy shock explains around 10 percent of inflation movements, in terms of FEVD. This is somewhat higher than in other studies of the Swedish economy, such as Lindé et al. (2009) and Adolfson et al. (2007), but still of the same order of magnitude. In line with earlier results from VAR estimations on Swedish data, the global shocks account for nearly half of the variation in Swedish consumer price inflation. During and in the initial period after the financial crisis, global supply shocks and to some extent also global demand shocks held up inflation. Starting around 2011, inflation was persistently low for an extended period of time. This downward trend was initially driven by contractionary monetary policy shocks and Swedish supply shocks. However, since 2013 global shocks have again played a greater role. In particular, negative global demand shocks have been responsible for the subdued inflation at the same time as the Krona was depreciating. As we can infer from the IRF above and will further discuss in the next section, the pass-through following demand shocks is in fact negative, implying that a depreciation of the Krona driven by a demand shock is accompanied by lower inflation. While the costs of foreign goods increased, Swedish firms decided to increase prices less (relative to steady state) due to the weak internal demand. Towards the end of our sample, expansionary monetary policy shocks have been the main force behind the rise in inflation. This coincides with a weak Krona.

[19] In Forbes et al. (2017), the Swedish demand shock accounts for over 50 percent of the variance in the Krona exchange rate.

4.4 Conditional exchange rate pass-through

Having assessed the large role of shocks other than the exogenous exchange rate shock in driving the fluctuations in the exchange rate and inflation, we now turn to evaluating the shock-dependent, i.e. *conditional* exchange rate pass-through (CERPT). As discussed in Section 3, the CERPT is based on the ratio of the responses of price levels to the response of the exchange rate to each shock at each horizon. In particular, in the following discussion we focus on the median ratio of the cumulative impulse responses.[20] From the point of view of a policy maker like the central bank, knowing the CERPT to prices is key to understanding the period of low inflation and depreciated Krona, as the one we observed in 2013–15. The historical decomposition of NEER and CPIF inflation above revealed that the negative global demand shock was the major driver of these developments. Indeed, the developments during this period in the Euro Area, which is Sweden's main trading partner, were weak. Using a rule-of-thumb that implies a positive, although incomplete, pass-through from exchange rate to prices would have supported the view of a positive effect on inflation, coming from the depreciated Krona. Instead, knowing that depreciations driven by demand shocks do not feed through to consumer prices or, rather, that the demand channel dominates the exchange rate channel in these cases, one would instead have expected more subdued inflation developments coming from the weak global demand.

Figure 3 reports the conditional pass-through to consumer prices after a 1 percent depreciation of the Krona, as the median ratio of cumulative responses of consumer prices relative to the exchange rate. We note that there are some dynamics over the first four, for some shocks up to eight, quarters but that the CERPT is practically constant from the two-year horizon and on. We take this as evidence that the effects of exchange rate movements have fully fed through after two years. In what follows, we will thus distinguish between the pass-through on impact and in the medium to long term only, referring to them as the short- and long-run pass-through. The long run thus refers to the two-year horizon and on. The average elasticity corresponds to the average pass-through, where the shocks are weighted with their share of the forecast error variance decomposition of the Krona exchange rate.[21] We find the average pass-through to consumer prices to be equal to 3 percent in the long run,

[20]As we can see from Figures B.1–B.6, in most cases the sign of the 68 percent probability bands coincides with the sign of the median ratio and does not contain zero. Hence, while there is naturally some uncertainty around the CERPT, we are generally confident about their sign and order of magnitude.

[21]The FEVD is only available from the first period after the shock hits. Hence, to compute the average elasticity on impact, we assign the weight of the first horizon to the impact responses.

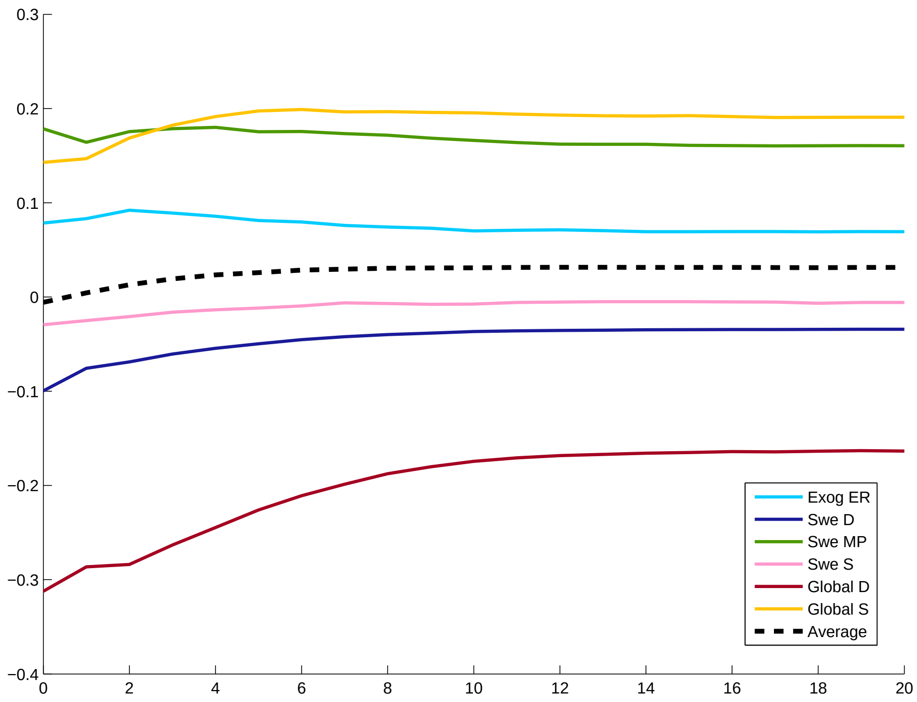

Figure 3: Exchange rate pass-through to CPIF by shock and on average across 20 quarters

which coincides with what Gagnon and Ihrig (2004) find for the period 1993-2003 with univariate regressions.[22]

The highest positive pass-through is obtained following the global supply shock and is close to 15 percent in the short and 20 percent the long run. This is in line with the findings in Forbes et al. (2015), where the global supply shock is the one to generate the highest pass-through, at least in the long run. The global supply shocks have rather large effects on inflation, which are only partly, if at all, offset by monetary policy. As inflation and output move in opposite directions, it is not clear what monetary policy reaction, and thus size or even sign of exchange rate response, to expect – keeping in mind a standard policy maker's objective to minimize deviations of inflation and output from their trends, this would largely depend on what weights a policy maker assigns to each objective. This may be a reason why inflation responses are large given the size of the exchange rate movement.

[22]An average pass-through of a similar magnitude is also found for Sweden in Forbes et al. (2017), based on a model similar to ours. They also report reduced-form estimates of ERPT for Sweden between 1 percent and -6 percent for different sub-samples (not significantly different from zero).

The global supply shock is followed by the monetary policy shock, with the second-highest CEPRT of just above 15 percent across all horizons. After a negative shock to the repo rate, firms face higher demand, since the expansive monetary policy stimulates the economy. The demand effect allows them to increase prices. Moreover, they face higher costs for foreign products due to the depreciation of the Krona and transfer the increase in costs to the consumers. Both of these factors lead firms to increase consumer prices. Comparing to the studies by Forbes et al. (2015) and Comunale and Kunovac (2017), for the UK and the Euro Area respectively, we find that the monetary policy shock features the largest or second-largest CERPT to consumer prices in those as well, although its size is lower in the short run. In Forbes et al. (2017), the monetary policy shock is the only shock found to generate a positive pass-through for all of the 26 countries for which they estimate the model, with a median across countries of around 30 percent after two years.

The CERPT to consumer prices after an exogenous exchange rate shock is just below 10 percent in the short run and around 5 percent in the medium and long run. This long-run estimate is in line with the reduced form estimate in Gagnon and Ihrig (2004) and slightly higher than the reduced-form estimate for Sweden in Forbes et al. (2017).

Following the two demand shocks in the model, the CERPT is negative. Thus, when the economy is hit by a negative demand shock, even if the Krona depreciates, firms are not willing to transfer the increase in costs to consumers, but instead lower their price increases (relative to steady state). Note that, for the domestic demand shock, the negative ERPT is in fact imposed on impact through the sign restrictions summarized in Table 1. However, this is not the case for the domestic demand shock in the long-run nor for the global demand shock at any horizon. Finding a negative pass-through following the domestic demand shock is common also in earlier studies. That the pass-through is negative after the *global* demand shock, however, is novel to our study and thus appears to be specific to Sweden. It is not surprising, at the same time, given the high correlation of Swedish variables – including inflation – with their trade-weighted foreign counterparts. Moreover, in the short run the CERPT following the global demand shock is as large as -30 percent and stays negative over all horizons, reaching around -15 percent in the long run. That the CERPT after demand shocks is negative and sizeable is an important finding, given that demand shocks account for a substantial share of the variation in the exchange rate. Our forecast error variance decomposition shows that they account for about 40 percent of the variation.[23] More than a third of the observed movements in the exchange rate may thus be accompanied by movements in inflation of the opposite sign compared to any rules-of-thumb or conventional wisdom. It is then not surprising that the average pass-through is very close to zero.

Finally, we note that even the Swedish supply shock features a negative CERPT, but very close to zero. The responses of the repo rate and the exchange rate contain zero, as discussed in Section 4.2 above, and the CERPT should therefore be interpreted with some caution. Even if the response of inflation is consistently negative, the fact that the bands around the exchange rate response are large and roughly centered at zero will imply that the same applies also to pass-through. We note that the median of the pass-through distribution cannot be easily inferred by looking at the median responses of inflation and the exchange rate in cases such as these, when the distribution of the exchange rate response contains zero.

From the above results, we gain some understanding about how misleading it can be to consider a rule-of-thumb for the ERPT based on an average value or on reduced-form estimates of exogenous exchange rate shocks. If the economy's behaviour is mostly explained by a global supply shock, the assumed response of consumer prices would be much lower than the effective one. If the economy's behaviour is mostly explained by a local or global demand shock, price-setters would act in the opposite way than the rule-of-thumb suggests. Having a better understanding of the shocks moving the exchange rate is key for the policy maker to manage the responses appropriately.

5 CERPT to Swedish import and consumer prices – alternative model

In this section we present an alternative BVAR model, that uses partly different data and identification strategy. In our benchmark model in the previous section, we studied the CERPT to consumes prices following each of the six identified shocks. In this alternative specification, we now also include import prices. Our baseline model relied on data on foreign quantities, which had the advantage that we could use more

[23]We note that, in our estimations, about a fourth of this can be attributed to global demand shocks. Forbes et al. (2017) also find demand shocks to be important in their estimates for Sweden, finding a smaller role of global shocks. Instead, the domestic demand shock represents over 50 percent of the FEVD. This is in contrast with our results, in particular during the recent financial crisis, when negative global demand shocks were more important than negative domestic demand shocks as drivers of the Krona movements. We note also that Forbes et al. (2017) estimate a smaller model, identifying domestic demand, supply and monetary policy shocks and two global shocks, but not the exogenous exchange rate shock. This complicates comparison with their estimates.

reliable measures for our identification without concerns about the measurement problems related to the import price series we have available. A disadvantage, however, is that we could not study pass-through to import prices in addition to final consumer prices. In what follows, we will exclude foreign quantities from our model and instead include import prices, and will thus be able to say something about the CERPT also to those. We will also obtain a complementary set of results for consumer prices. As identification here is based on import prices and those may be surrounded by measurement problems, our previous specification is our preferred one. There are some problems with the results in the alternative model, as we will discuss in more detail below. Our obtained estimates are still broadly in line with expectations, however, and the results are comparable to those from most similar studies on other countries, why they still provide a useful robustness check and relevant insights regarding the pass-through from exchange rates to import prices as well as from import to consumer prices.

We begin with a presentation of the identifying assumptions that underlie our model estimation. We then discuss the impulse response functions and decompositions of the exchange rate and both the import price and consumer price inflation rates, and finally present the CERPT.

5.1 Identification

The restrictions we impose are summarized in Table 3, and are based on those used by Forbes et al. (2015) from a standard open-economy DSGE model building on Benigno (2009) and Corsetti et al. (2010).[24] The sign restrictions are again imposed on impact.[25]

We again rely on the assumption that Sweden is a small open economy, and that Swedish domestic shocks thus have no effect on global variables. Hence, none of the domestic shocks can affect global export price inflation in the short nor in the long run. Moreover, we again assume that only supply shocks are allowed to affect

[24]We now use KIX-CPI as proxy of global export price inflation. An alternative measure of foreign export price inflation is the Global Export Price Index, GLEXPI. However, this export price index is based on import weights for the different countries. To the extent that large parts of Swedish imports go directly into the production of export products, GLEXPI is a suboptimal indicator of price pressures from the outside world. Moreover, data are available only from 1999. For this reason we have chosen the KIX-CPI, an average price index for the foreign countries, where the countries are weighted based on their trade relevance for imports, export and third-country effects. These weights are the same ones used to calculate the effective exchange rate of the Swedish Krona.

[25]Unlike Forbes et al. (2015), we impose the sign restrictions only for the first quarter, not the first 2 quarters.

Table 3: Identifying restrictions

	Exog ER shock	SWE demand shock	SWE mon pol shock	SWE supply shock	Global demand shock	Global supply shock
			Short-run restrictions			
Δ SWE nom ER	+	-	-			
Δ SWE CPIF	+	+	-	-		
SWE int rate	+	+	+			
Δ SWE GDP		+	-	+		-
Δ KIX CPI	0	0	0	0	+	
Δ SWE IM pr	+					+
			Long-run restrictions			
Δ SWE nom ER						
Δ SWE CPIF						
SWE int rate						
Δ SWE GDP	0	0	0		0	
Δ KIX CPI	0	0	0	0		
Δ SWE IM pr						

Note: The signs on the diagonal are included in the table for clarity, and are only there for normalization purposes.

the level of GDP in the long run, thus imposing zero long-run restrictions on GDP for the remaining shocks. Note that, as the present specification does not include a measure of foreign GDP, Swedish GDP now enters in growth rates and not in relative terms. The sign restrictions used to identify the domestic shocks are generally the same as in the benchmark model: the demand shock is assumed to push up consumer price inflation, GDP and the interest rate while appreciating the exchange rate, a monetary policy shock that increases the interest rate is assumed to bring about a drop in consumer price inflation and GDP as well as an appreciation in the exchange rate, and the domestic supply shock is assumed to move GDP and Swedish consumer price inflation in opposite directions. The only change to the identification of domestic shocks is that the shock to the nominal exchange rate is now restricted to cause an increase in Swedish import in addition to consumer price inflation when the exchange rate depreciates.[26]

[26] We note that there may be some problems related to the measurement of Swedish import prices. We discuss this issue further in Section 6 below. Our estimations, using the import price index IMPI

For the global shocks, as in the previous section, we assume that the supply shock can affect the GDP level in the long run while the demand shock can not. As we no longer include a measure of foreign GDP, we rely on the restrictions on Swedish GDP. We impose that the impact effect on Swedish GDP should be negative for a positive effect on prices following the global supply shock, to ensure that we are capturing supply rather than persistent demand shocks.[27]

5.2 Impulse response functions

The impulse response functions are reported in Appendix D, Figures D.1 to D.6. The impulse response functions have again been rescaled so as to cause a one percent depreciation of the Swedish Krona after 4 quarters, just as in Appendix B. The impulse responses look similar to the ones obtained before, with a few exceptions. We discuss those briefly and comment on the responses of import prices, which are new to this specification.

After a risk premium shock that depreciates the Krona, shown in Figure D.1, we observe an increase in both import and consumer price inflation, in line with restrictions, with the response of the former being much stronger than the latter. The repo rate increases in line with the restriction, but now we also observe an increase in Swedish GDP. This is a short-term effect, that becomes zero after a number of quarters, as imposed by the long-run restriction. In the previous BVAR model we observed a slightly negative, but indeed uncertain, response of the GDP after the depreciation of the Krona. The present model instead indicates that the effect on GDP from the exchange rate depreciation seems to dominate the effects from higher inflation and interest rates.

Following the negative Swedish demand shock, shown in Figure D.2, GDP and CPIF fall causing a decrease in the repo, and the Krona depreciates just as in the previous specification. Import prices appear to decrease on impact after the exchange rate depreciation, judging by the median response. Looking at the probability intervals, though, it is more fair to say that the response is zero. Although we leave the sign

as well as alternative series, have shown that Swedish import prices do not always tend to move in the expected direction. Unlike Forbes et al. (2015), we are therefore restricting both import and consumer price inflation to react positively to an exogenous exchange rate depreciation. Note that this issue is present also in Comunale and Kunovac (2017), and that the unexpected movements in the import prices following some shocks therefore may not be related to measurement issues only in Swedish data.

[27] Just as before, all the elements on the diagonal of the upper matrix in table 1 are normalized to be positive, why the price responses of KIX CPI and Swedish import prices are set to plus following the shocks to global demand and supply, respectively, and the restriction on GDP is negative.

of the import price response unrestricted, one may expect import prices to always move with the exchange rate, so that a depreciation implies an increase in import prices following all shocks. The same is not necessarily to be expected for final consumer prices, and we have also seen that the opposite holds true following several of the shocks. To import prices, however, it is reasonable to expect a higher and positive pass-through. The pass-through to import prices in the long run is indeed positive, but our results indicate that in the short run this is not the case. There may be several explanations behind this. The negative response of import prices at the same time as the Krona depreciates could indicate a strong pricing-to-market behaviour from the side of the importing firms. Since local demand decreases, importing firms may decide to decrease prices despite the higher cost for foreign goods. There is also a risk that the unexpected response of import prices reflects measurement problems with the import price series at hand. Therefore, we have run sensitivity checks on alternative import price series, obtaining similar results. Moreover, this result is not specific to our study, as Comunale and Kunovac (2017) obtain similar IRFs on Euro Area data. In Forbes et al. (2015), the median response of the import price goes in the expected direction, but the distribution is also centered around zero following the domestic demand shock.

We next consider the monetary policy shock in Figure D.3. Following the drop in the repo rate, the response of import prices is not different from zero in a probabilistic sense, while the response of consumer prices is very large. Hence, the response of consumer prices does not seem to be driven primarily by the pricing behaviour of import firms. Instead, it seems to be dominated by the effects of increased demand and higher resource utilization on domestic price setters. We note that the size of the on-impact response of consumer prices in our estimation is not in line with other estimates of responses to monetary policy shocks, and should therefore be interpreted with some caution. This is an important difference compared to the benchmark model in Section 4 and one of the reasons why the previous specification is our preferred one.

The domestic supply shock required to generate an exchange rate depreciation is of the opposite sign compared to our benchmark model. In Figure D.4, we observe a drop in GDP and an increase in CPIF. These are accompanied by an increase in the repo rate and a weaker Krona, judging by the median response. This implies a positive median pass-through both to import and consumer prices, while it was slightly negative for the benchmark model. The response of the Krona is, however, not different from zero in a probabilistic sense. The wide uncertainty of the exchange rate response after the domestic supply shock is familiar from our previous specification and also common to similar studies for the UK (Forbes et al., 2015) and the Euro Area (Comunale and Kunovac, 2017). The response of import prices is basically centered on zero. Given that the same is true for the exchange rate response, the estimate of the pass-through to import prices following Swedish supply shocks is very uncertain.

Following the global demand shock, shown in Figure D.5, foreign prices as well as consumer prices and GDP in the Swedish economy decrease, which brings about a drop in the repo. The Krona weakens, although the 90 percent interval includes zero. Import prices go down slightly on impact but are basically unchanged in the long run, with the drop in foreign prices and the exchange rate depreciation roughly offsetting each other. The median response is slightly negative at first, before turning positive, why our reported pass-through to import prices is negative in the short run and positive in the long run.

A negative global supply shock, finally, shown in Figure D.6, generates a fall in Swedish GDP and an increase in consumer prices together with a depreciating Krona. Import prices now clearly rise, with both foreign prices and the exchange rate rising. The median response of import prices is much larger than the one of consumer prices. Hence, the pass-through from import to consumer prices is very low following global supply shocks.

For import prices, the results are uncertain in general. This is obvious from the rather wide probability bands following most of the shocks. The exception is the global supply shock, where the responses are normalized by the sign of the response of the import prices due to the ordering of the variables – here, we instead observe more uncertain responses of the remaining variables as a result. This may reflect the previously discussed measurement problems related to the import price series. Moreover, there is larger uncertainty around the CERPT to consumer prices, compared to what we obtained with the benchmark model. These are additional reasons why we prefer our benchmark specification for studying pass-through to aggregate consumer prices. Nevertheless, the results generated by our alternative specification still shed some light on the transmission of exchange rate fluctuations along the pricing chain. To strengthen the reliability of our results, we present sensitivity checks on alternative import price series in Section 6 below.

5.3 Decompositions

We first present the forecast error variance decomposition of the exchange rate and then discuss the historical decompositions for the exchange rate and the CPIF inflation rate, as well as the import price inflation rate.

Table 4: Forecast error variance decomposition (FEVD) of the the nominal effective exchange rate

	Exog ER	Swe D	Swe MP	Swe S	Global D	Global S
NEER	16	21	8	10	27	18

Note: The numbers represent percentages of the forecast error variance due to each shock.

Table 4 presents the share of the exchange rate forecast error variance that is explained by each of our six shocks. We observe some differences compared to the benchmark specification. The global shocks now account for a total of 45 percent of the exchange rate fluctuations. The importance of the domestic shocks has generally decreased at the expense of the share of the two global shocks. It is in particular the global demand shock that now turns out to be a far more dominant driver of the exchange rate. Most importantly for our purposes, despite the differing weights assigned to the different shocks, the exogenous shock to the exchange rate still accounts for a relatively small fraction of exchange rate fluctuations. In fact, its share is now smaller than in the benchmark specification. It now explains merely 16 percent – again far from being a dominant driver.

Figures 4–6 show the role of each shock for the deviations across time of the annual change in NEER, import and consumer prices from their historical averages.[28] The large depreciation of the Krona during the financial crisis is almost entirely attributed to global demand shocks, which have also had a weakening effect on the Krona in the last few years. Monetary policy shocks play a much smaller role in the decomposition of the exchange rate than in our benchmark model. From Figure 5 we can see that monetary policy shock have, on the contrary, been a very important driver of CPIF inflation. This result is to be expected, given the implausibly large on-impact response of CPIF inflation to the monetary policy shock, discussed in the previous section. We thus interpret the results related to the monetary policy shock with some caution.

Figure 6 shows the historical decomposition of the import price inflation. The Swedish and the global supply shocks are the two most important drivers of the

[28] For the historical decompositions of the remaining Swedish variables, see Appendix E.

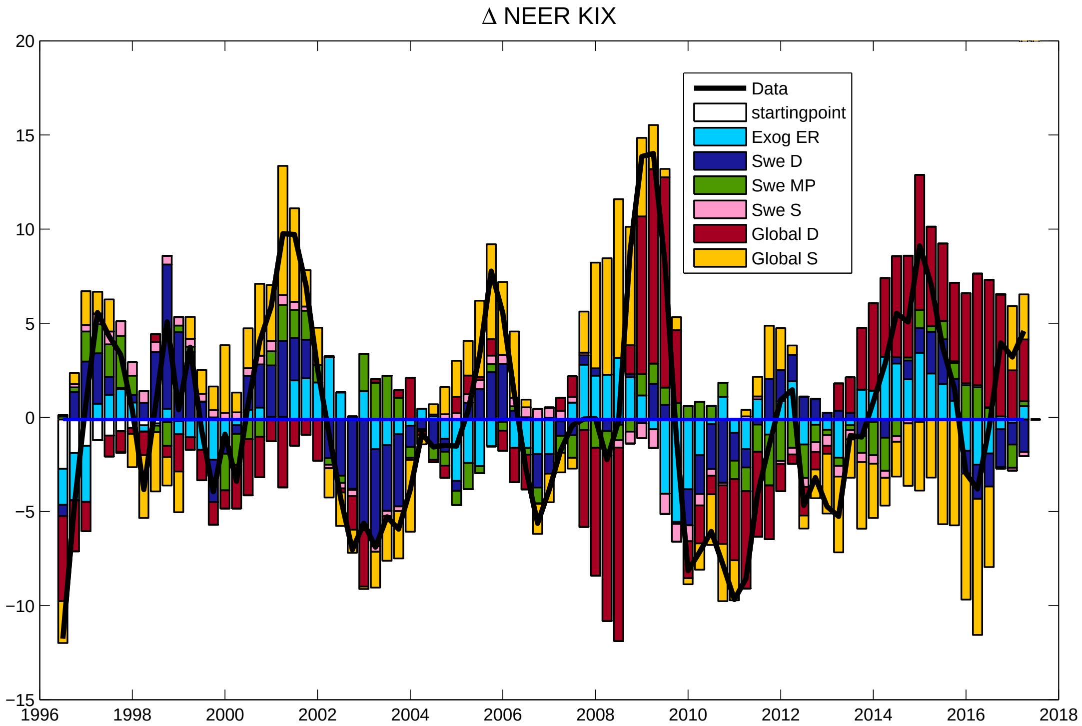

Figure 4: Historical decomposition of the nominal effective Krona exchange rate, year-on-year changes

import price movements over our sample and, as we will see below, they also feature a high pass-through from the exchange rate. The surge in import prices around the time of the latest crisis, coinciding with the large Krona depreciation, is mostly due to negative global supply shocks. However, the increase in import prices was not dramatic, once we compare it with its historical movements, which is due to the simultaneous contribution from positive Swedish supply shocks. Supply shocks – Swedish and global – were also the main drivers behind the low import price inflation in the years following the financial crisis. Import prices increased again in 2014 and the first half of 2015, coinciding with the large depreciation of the Krona. The reason for this development can be attributed mostly to the negative global demand shocks. More recently, we observe a substantial pick-up in import prices. The main driver is once again the global supply shock. As the sequence of positive supply shocks that held down import price inflation during 2015 and 2016 wears off and global supply shocks turn negative, inflation quickly rises, supported further by a weak exchange rate resulting from negative global demand.

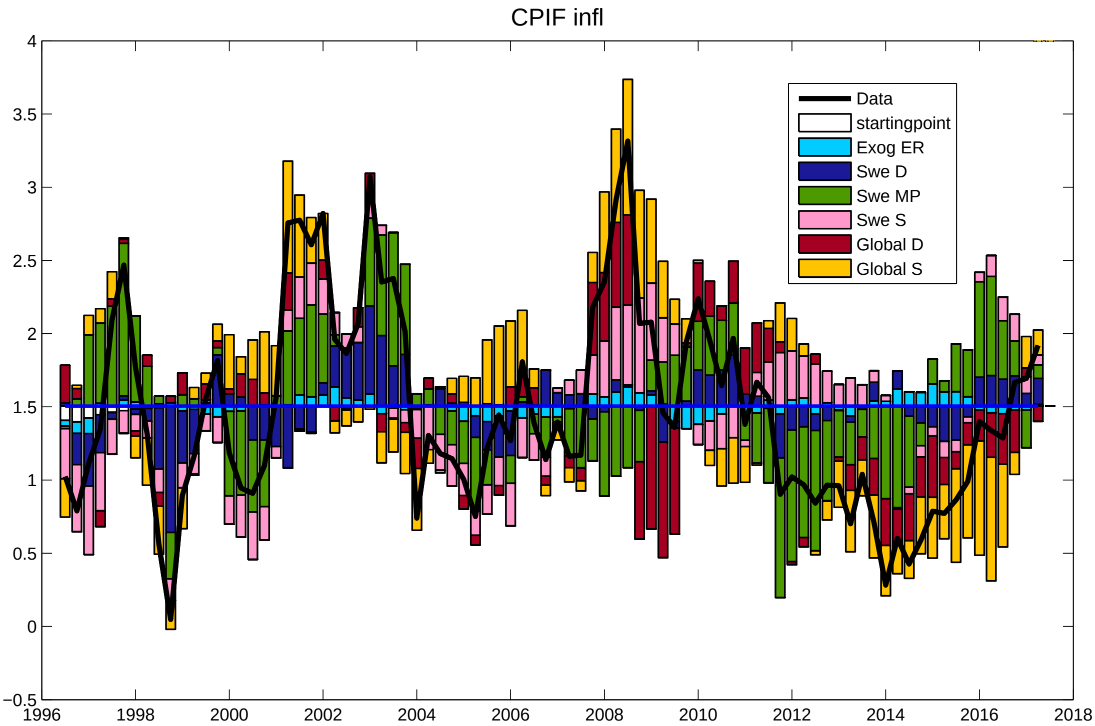

Figure 5: Historical decomposition of the CPIF inflation, year-on-year changes

5.4 Conditional exchange rate pass-through

We first present the CERPT to import prices, and then proceed with comparing the CERPT to consumer prices obtained in this model and the previous one.

Figure 7 shows the CERPT to import prices, as the median ratio of cumulative responses of import prices relative to the exchange rate. The average exchange rate pass-through to import prices is 20 percent in the short run and closer to 30 percent in the long run. We can compare this to the univariate model results from Campa and Goldberg (2005). They estimate a higher average elasticity for Sweden, finding a short-run pass-though equal to 48 percent and a long-run pass-through equal to 38 percent, but their sample period is from 1975 to 2003. Our structural model shows that the pass-through can be as high as 100 percent on impact and 80 percent in the long run after a global supply shock. As Forbes et al. (2015) find for the UK, the global supply shock features the largest pass-through to import prices. The Swedish supply shock also features a high pass-through, but from the IRFs we noted that the response of the exchange rate after a Swedish supply shock is not different from zero in a probabilistic sense. The exogenous exchange rate shock and the demand shocks

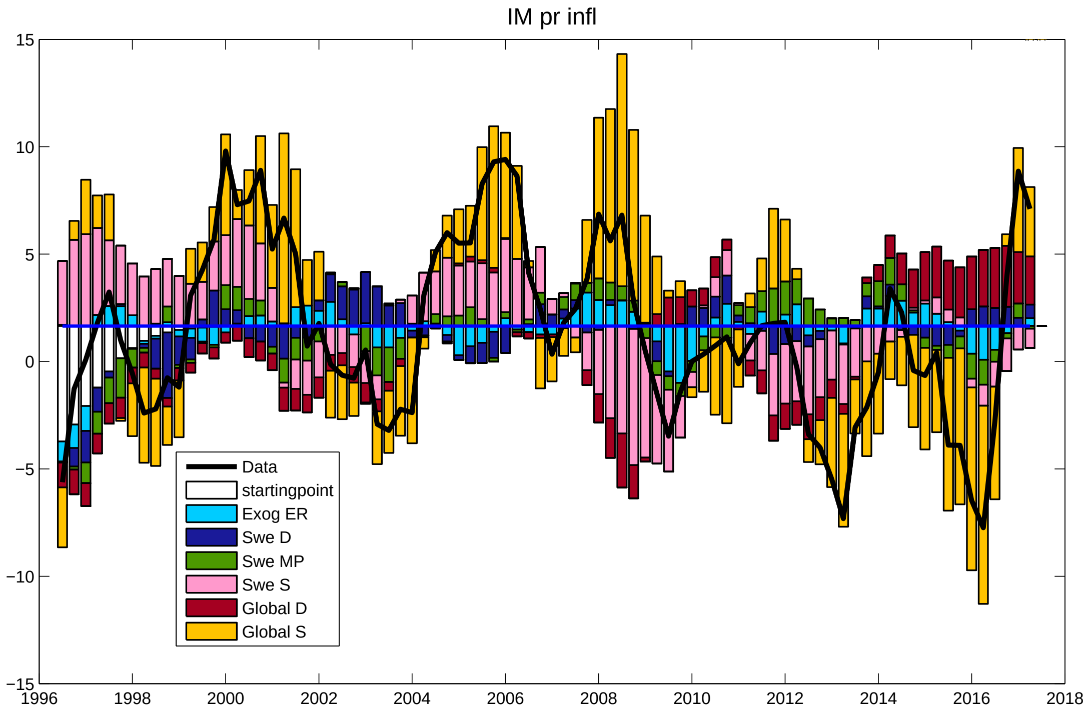

Figure 6: Historical decomposition of the import price inflation, year-on-year changes

– both local and global – feature a long-run pass-through to import prices below average, and the global demand shock even features a negative pass-through in the first 6 quarters. After a 1 percent depreciation of the Krona due to a negative global demand shock, import prices drop by 0.25 percent on impact, relative to steady state price growth, before slowly turning back up. This behaviour of import prices, despite an increase in the cost of foreign goods, suggests that the decreased global demand forces the importing firms to decrease their margins in order to keep their market shares. The monetary policy shock features a negative pass-through on impact, that becomes zero after 1 year. We recall from Section 5.2, however, that the response of import prices to the monetary policy shock is surrounded by very large uncertainty. In summary, the pass-through to import prices is positive in the long-run following all shocks, as expected. However, there is large variation in magnitudes. The largest pass-through is obtained after the global supply shock. In the short run, the CERPT following global demand shocks is negative. While this is certainly not implausible for final consumer prices, it is perhaps less intuitive for import prices. Import prices are reported as imported goods cross the border and tend to be highly correlated with the exchange rate, why we would expect pass-through to always be positive. This result is different from what Forbes et al. (2015) find for the UK, where the global demand shock features a pass-through that is positive and even larger than the one after the global supply shock.

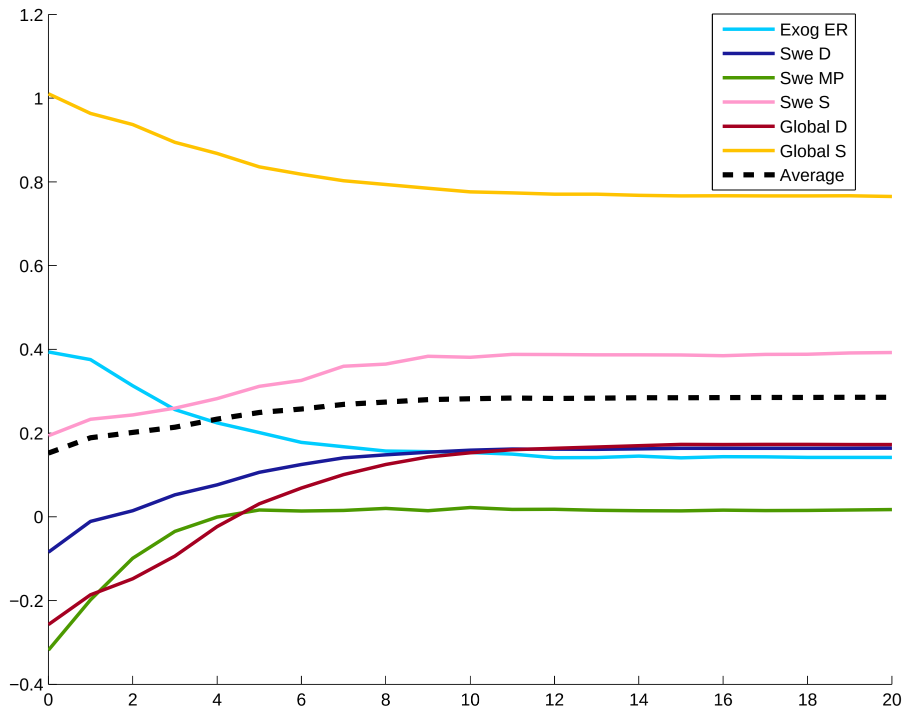

Figure 7: Exchange rate pass-through to import price deflator by shock and on average across 20 quarters

In Figure 8, we report the conditional pass-through to consumer prices from the alternative model, as the median ratio of cumulative responses of consumer prices relative to the exchange rate. We find the average pass-through to consumer prices to be equal to 2 percent in the long run, similar to the estimate from our benchmark model. It is a well established empirical finding in the literature that the ERPT to border prices is incomplete and the ERPT to consumer prices is lower than the one to border prices.[29] Our results are thus in line with earlier literature, as we find that

[29]See Campa and Goldberg (2005) for evidence of incomplete pass-through to import prices for 23 OECD countries and Burstein and Gopinath (2014) for a more recent review of the literature. Possible reasons for an incomplete pass-through are nominal rigidities due to menu costs, the composition of imported goods and their role for the production of consumer goods, the extent of the use of foreign versus local currency pricing, the level of competition in the industry that can induce

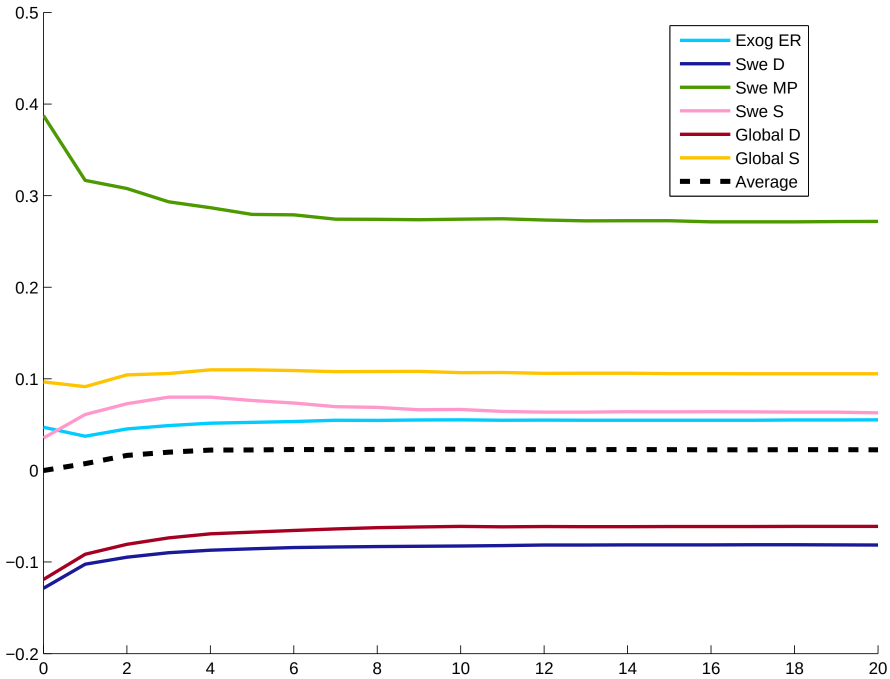

Figure 8: Exchange rate pass-through to CPIF by shock and on average across 20 quarters

the average pass-through to consumer prices is considerably lower than the one to import prices.

The highest positive pass-through to consumer prices is now obtained following the monetary policy shock, reaching 40 percent in the short run and around 30 percent in the medium and long run. Both the higher demand and higher costs of imported inputs lead firms to increase consumer prices, and considerably more so than import prices. We have pointed out before that the response of CPIF inflation to the monetary policy shock is very large. This raises some uncertainty regarding its CERPT estimates. Consistently with the previous model, following an exogenous exchange rate shock the pass-through to consumer price inflation is around 5 percent in the medium and long run. As before, the Swedish demand shock and the global demand shock generate a reversed-sign exchange rate pass-through, this time of about equal size. Again, a large portion of the depreciation of the exchange rate would be accompanied by lower consumer prices. We emphasize that the pass-through is

pricing-to-market, the perceived persistence of the shocks hitting the economy and the firms' hedging strategy against exchange rate movements.

again negative after the *global* demand shock – a finding that, albeit specific to our study, is not specific to the previous model but prevails across different identifying assumptions.

Hence, the robust findings between this model and the previous one are the following: 1) the role of the demand shocks in generating a reverse-sign CERPT; 2) a small positive CERPT following the exogenous exchange rate shock; 3) the limited role of the exogenous exchange rate shock for the FEVD of the exchange rate; 4) a large variation in CERPT across shocks; and 5) an average pass-through to consumer prices that is close to zero. The first result is in line with the idea that price setters look at the demand side, beyond the effect of the exchange rate on their costs. The second and third results are very important in highlighting the limitations of DSGE models, where most of the exchange rate movements are explained by the risk-premium shock with a positive and possibly also high ERPT. Finally, the last two results point to the difficulty of relying on "rules-of-thumb", given that the shock-dependent measures of ERPT can be very different from the average one.

6 Data sensitivity analysis

As mentioned in Section 2, there is some degree of freedom in choosing the measures of prices to include in the model. Moreover, monetary policy in Sweden has been conducted also with asset purchases since 2015 in addition to changes in the interest rate, which we do not explicitly account for in our previous specifications. To assess the importance of our data choices, we have conducted a set of sensitivity checks.[30]

The exchange rate movements are closely tied to monetary policy, at least in theory. In recent years, unconventional monetary policy measures have become more and more relevant in many economies including Sweden, making the policy rate an insufficient indicator of the overall stance of monetary policy. In order to account for this, we have estimated the model using a measure of monetary policy that also accounts for the effects of asset purchases. This measure is a shadow interest rate estimated by De Rezende and Ristiniemi (2018), that we detrend with the same measure of the neutral rate as previously. The shadow interest rate diverges from the official repo rate from the beginning of 2015, when the Riksbank started purchasing assets in order to make monetary policy more expansionary, in addition to using the traditional interest rate tool. The results we obtain are not much affected, which is

[30]We do not report detailed results for the sensitivity analysis in the paper. They are available from the authors upon request.

likely due to the fact that the interest rate measure changes only in the last couple of years of our sample.

There may be problems related to the measurement of Swedish import prices, due to the way they are reported. While the norm is that prices should primarily be reported in their invoicing currency, reporting in Swedish Kronor is always accepted. Around half of the prices are reported in Swedish Kronor, and it is not clear that the exchange rate used in the conversion is the one that most accurately mirrors the relevant value of the Krona. At the same time, our results for the import prices are not always in line with expectations, which raises further questions regarding the accuracy of the data. For these reasons, we have tried to use different import price measures. We have obtained similar results by running the model with the import price deflator for total imports of goods and services, obtained from data on imports in current and constant prices from the National Accounts. In an attempt to obtain a cleaner link between import and consumer prices, we have also tried using a CPI index for imported goods. All these measures deliver similar results.

7 Conclusions

In this paper we have used a structural econometric approach to evaluate the exchange rate pass-through from the Swedish Krona to consumer and import prices, depending on the shock behind the exchange rate movements – the conditional exchange rate pass-through (CERPT). Our results show that relying on a "rule-of-thumb" can be highly misleading, since the ERPT varies a lot depending on the shock hitting the economy. This is particularly important for a policy maker like the central bank, that has to take into account the effect of exchange rate movements on prices when deciding on its policy stance.

For our analysis we use two alternative six-variable BVAR models, where the shocks are identified through zero short-run and long-run restrictions as well as sign restrictions. We are able to identify 4 domestic shocks (supply, demand, monetary policy and exogenous exchange rate shocks) and 2 global shocks (supply and demand shocks). Our benchmark model is the preferred one for studying CERPT to aggregate consumer prices, but our second model allows us to also shed some light on the CERPT to import prices and the robustness of the main finding to different data and identification restrictions.

We find an average pass-through to consumer prices that is smaller than the one to import prices. The average ERPT to import prices is around 20 percent, versus an ERPT to consumer prices that is close to zero. There is a large variation in the CERPT following the different shocks, however, pointing to the limitations of using univariate approaches to study the effects of exchange rate fluctuations on prices. The highest CERPT is obtained following global supply and monetary policy shocks for consumer prices, and global supply shocks for import prices. The risk-premium shock always features a small CERPT, of just under 10 percent in the short run and around 5 percent in the long run, and explains at most some 20 percent of the fluctuations in the effective exchange rate. This is an important finding to highlight the limitations of using models where the exchange rate is predominantly explained by its own exogenous shocks to assess the effects of the exchange rate movements on prices. Domestic and foreign demand shocks generate a CERPT to consumer prices with a negative sign, between -5 percent and -20 percent for consumer prices in the short and the long run, respectively. Hence, following demand shocks, price setters seem to be driven mainly by the demand side rather than the effect of the exchange rate movements on their costs. Similar studies on other countries generally find the CERPT following the domestic demand shock to be negative. That the CERPT is negative following also the global demand shock is novel to our study and may be related to Sweden's high openness and the fact that Swedish macro variables are highly correlated with their foreign counterparts. As foreign shocks are important drivers of the Swedish economy, the negative exchange rate pass-through following foreign demand shock has relevant implications for the expected movements of inflation and consequently for the conduct of monetary policy.

References

Adolfson, M., S. Laséen, L. Christiano, M. Trabandt, and K. Walentin (2013): "Ramses II-Model Description," Occasional paper series, Sveriges Riksbank.

Adolfson, M., S. Laséen, J. Lindé, and M. Villani (2007): "Bayesian estimation of an open economy DSGE model with incomplete pass-through," *Journal of International Economics*, 72, 481–511.

Arias, J. E., J. F. Rubio-Ramírez, and D. F. Waggoner (2014): "Inference Based on SVARs Identified with Sign and Zero Restrictions: Theory and Applications," Dynare Working Papers 30, CEPREMAP.

Beneš, J., A. Binning, M. Fukac, K. Lees, and T. Matheson (2009): *KITT: Kiwi Inflation Targeting Technology*, Reserve Bank of New Zealand.

Benigno, P. (2009): "Price stability with imperfect financial integration," *Journal of Money, Credit and Banking*, 41, 121–149.

Blanchard, O. J. and D. Quah (1989): "The Dynamic Effects of Aggregate Demand and Supply Disturbances," *American Economic Review*, 79, 655–673.

Bonomolo, P., V. Corbo, and J. Lindé (2018): "On the Sources of Business Cycle Fluctuations in Small Open Economies: Sweden 1995 - 2015," Mimeo.

Burstein, A. and G. Gopinath (2014): "International Prices and Exchange Rates," in *Handbook of International Economics*, ed. by E. H. Gita Gopinath and K. Rogoff, Elsevier, vol. 4, chap. 7.

Campa, J. M. and L. S. Goldberg (2005): "Exchange Rate Pass-Through into Import Prices," *The Review of Economics and Statistics*, 87, 679–690.

Christiano, L. J., M. Trabandt, and K. Walentin (2011): "Introducing financial frictions and unemployment into a small open economy model," *Journal of Economic Dynamics and Control*, 35, 1999–2041.

Comunale, M. and D. Kunovac (2017): "Exchange rate pass-through in the Euro Area," Working Paper, No. 2003, European Central Bank.

Corsetti, G., L. Dedola, and S. Leduc (2010): "Optimal Monetary Policy in Open Economies," in *Handbook of Monetary Economics*, ed. by B. M. Friedman and M. Woodford, Elsevier, vol. 3 of *Handbook of Monetary Economics*, chap. 16, 861–933.

De Rezende, R. B. and A. Ristiniemi (2018): "A shadow rate without a lower bound constraint," Mimeo.

Engel, C. (2014): "Exchange Rates and Interest Parity," in *Handbook of International Economics*, ed. by E. H. Gita Gopinath and K. Rogoff, Elsevier, vol. 4, chap. 8.

Forbes, K., I. Hjortsoe, and T. Nenova (2015): "The shocks matter: improving our estimates of exchange rate pass-through," External MPC Unit Discussion Paper No. 43, Bank of England.

——— (2017): "Shocks versus structure: explaining differences in exchange rate pass-through across countries and time," External MPC Unit Discussion Paper No. 50, Bank of England.

Gagnon, J. E. and J. Ihrig (2004): "Monetary policy and exchange rate pass-through," *International Journal of Finance and Economics*, 9, 315–338.

Gopinath, G., O. Itskhoki, and R. Rigobon (2010): "Currency choice and exchange rate pass-through," *American Economic Review*, 100, 304–36.

Hopkins, E., J. Lindé, and U. Söderström (2009): "The transmission mechanism and the financial crisis," Sveriges Riksbank Economic Review 2009:02, pag. 51-71.

Itskhoki, O. and D. Mukhin (2017): "Exchange rate disconnect in general equilibrium," Tech. rep., National Bureau of Economic Research.

Justiniano, A. and B. Preston (2010): "Can structural small open-economy models account for the influence of foreign disturbances?" *Journal of International Economics*, 81, 61–74.

Laubach, T. and J. C. Williams (2003): "Measuring the natural rate of interest," *Review of Economics and Statistics*, 85, 1063–1070.

Lindé, J. (2003): "Monetary Policy Shocks and Business Cycle Fluctuations in a Small Open Economy: Sweden 1986-2002," Working Paper Series 153, Sveriges Riksbank (Central Bank of Sweden).

Lindé, J., M. Nessén, and U. Söderström (2009): "Monetary policy in an estimated open-economy model with imperfect pass-through," *International Journal of Finance and Economics*, 14, 301–333.

Meese, R. and K. Rogoff (1983a): "The out-of-sample failure of empirical exchange rate models: sampling error or misspecification?" in *Exchange rates and international macroeconomics*, University of Chicago Press, 67–112.

Meese, R. A. and K. Rogoff (1983b): "Empirical exchange rate models of the seventies: Do they fit out of sample?" *Journal of international economics*, 14, 3–24.

Murchison, S. and A. Rennison (2006): "ToTEM: the Bank of Canada's new projection model," Technical Report 97, Bank of Canada.

Obstfeld, M. and K. Rogoff (2000): "The six major puzzles in international macroeconomics: is there a common cause?" *NBER macroeconomics annual*, 15, 339–390.

Shambaugh, J. (2008): "A new look at pass-through," *Journal of International Money and Finance*, 27, 560 – 591.

Strid, I. and P. Bonomolo (forthcoming): "Improving policy rate forecasts in central bank models," Staff Memo, Sveriges Riksbank.

Villani, M. (2009): "Steady-state priors for vector autoregressions," *Journal of Applied Econometrics*, 24, 630–650.

Villani, M. and A. Warne (2003): "Monetary policy analysis in a small open economy using Bayesian cointegrated structural VARs," Working Paper Series 296, European Central Bank.

A Appendix: Data series

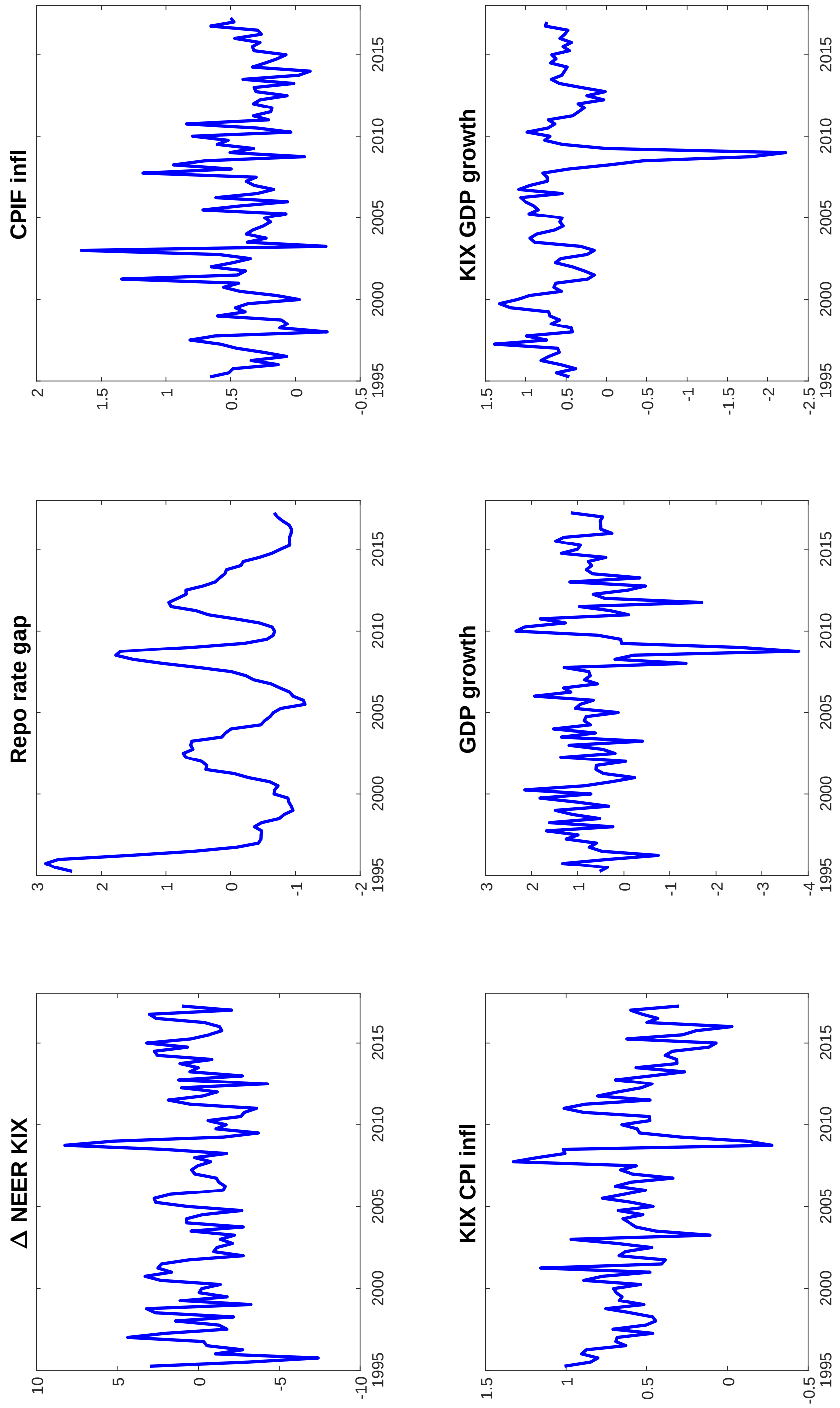

Figure A.1: Data series used for estimation. The repo rate gap is the difference between the policy rate and the neutral rate.

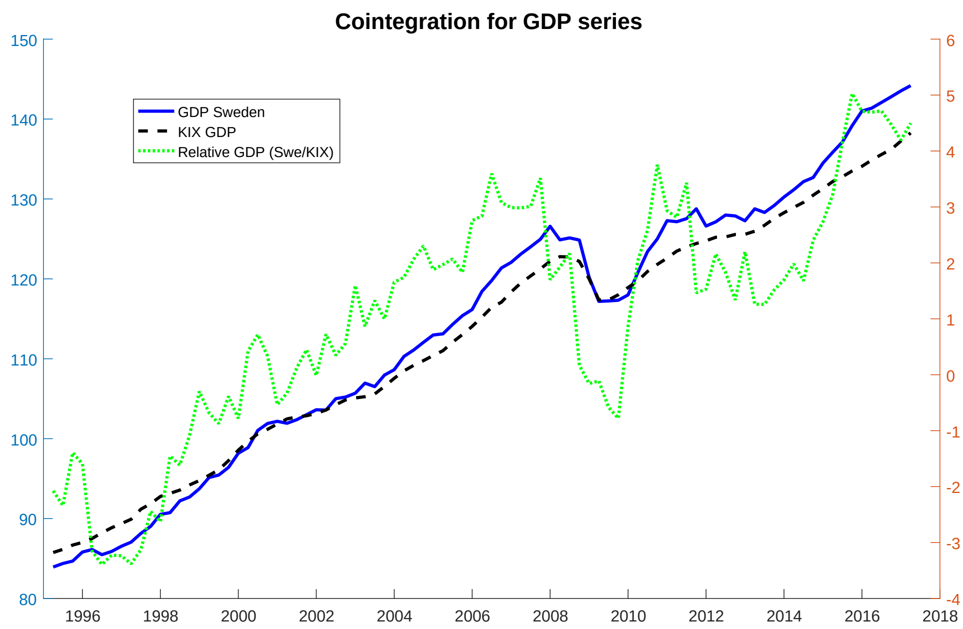

Figure A.2: GDP data series used for estimation. The GDP series are rescaled so as to equal 100 in the year 2000. The relative GDP is the log difference of Swedish GDP and KIX GDP.

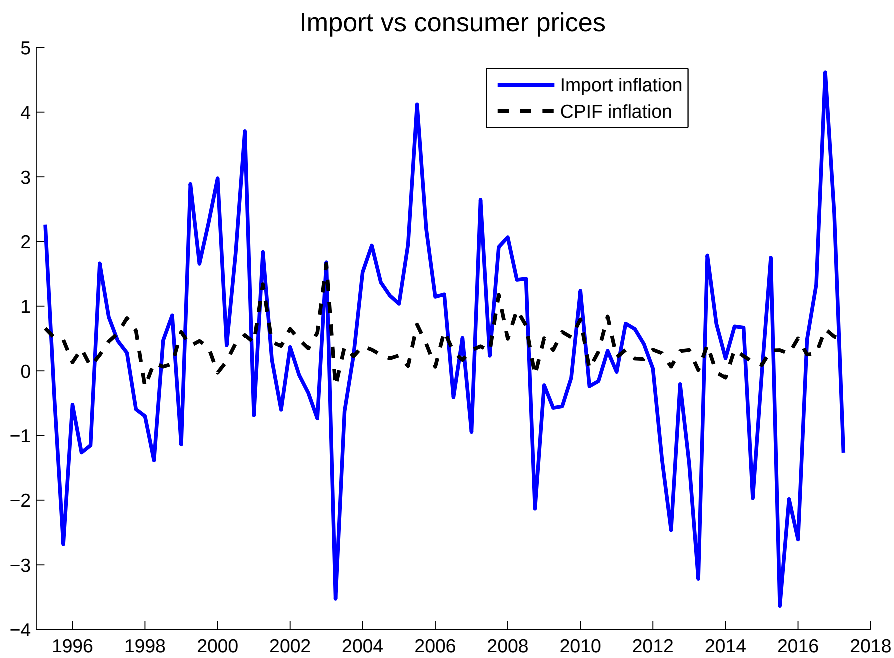

Figure A.3: Import and consumer price inflation series used for estimation

B Appendix: Impulse responses for benchmark model

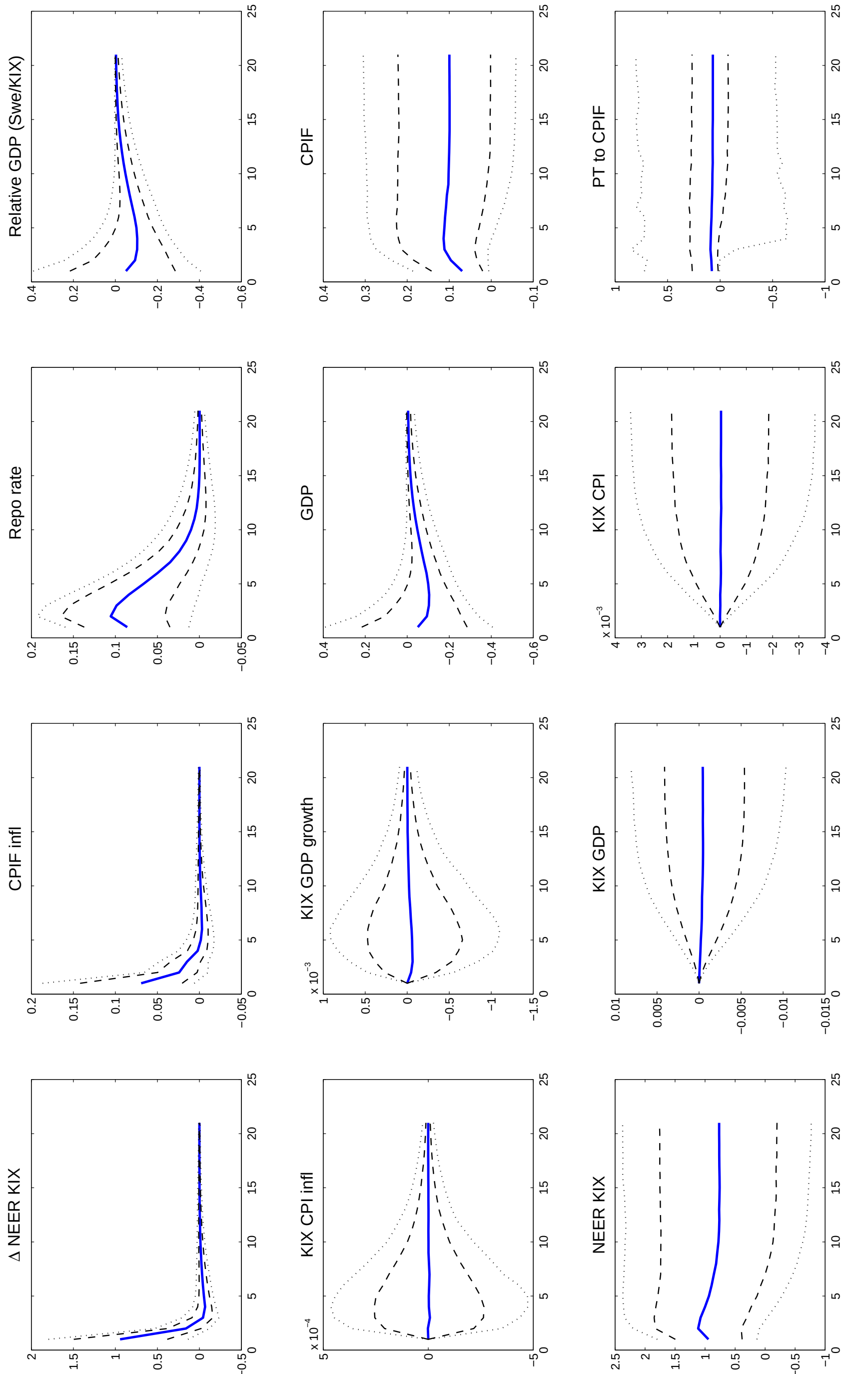

Figure B.1: Impulse responses to an exogenous exchange rate shock in the benchmark model. The graphs report the median impulse response (solid line) with the 68 percent interval (dashed lines) and the 90 percent interval (dotted lines). The responses are rescaled to cause an appreciation of the Swedish Krona by 1 percent after 4 quarters in the median case. The relative GDP is not expressed in percentage terms.

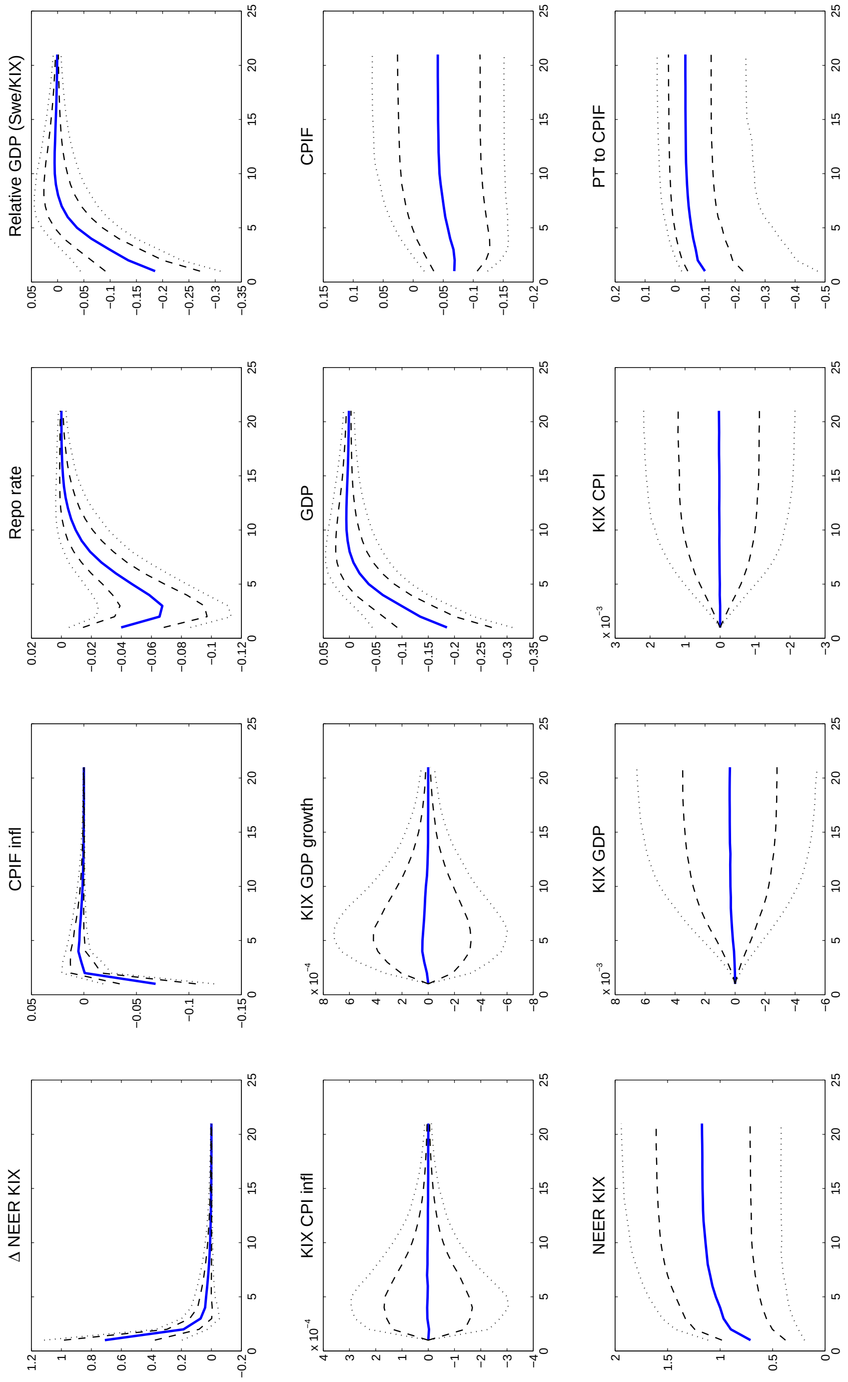

Figure B.2: Impulse responses to a Swedish demand shock in the benchmark model. The graphs report the median impulse response (solid line) with the 68 percent interval (dashed lines) and the 90 percent interval (dotted lines). The responses are rescaled to cause an appreciation of the Swedish Krona by 1 percent after 4 quarters in the median case. The relative GDP is not expressed in percentage terms.

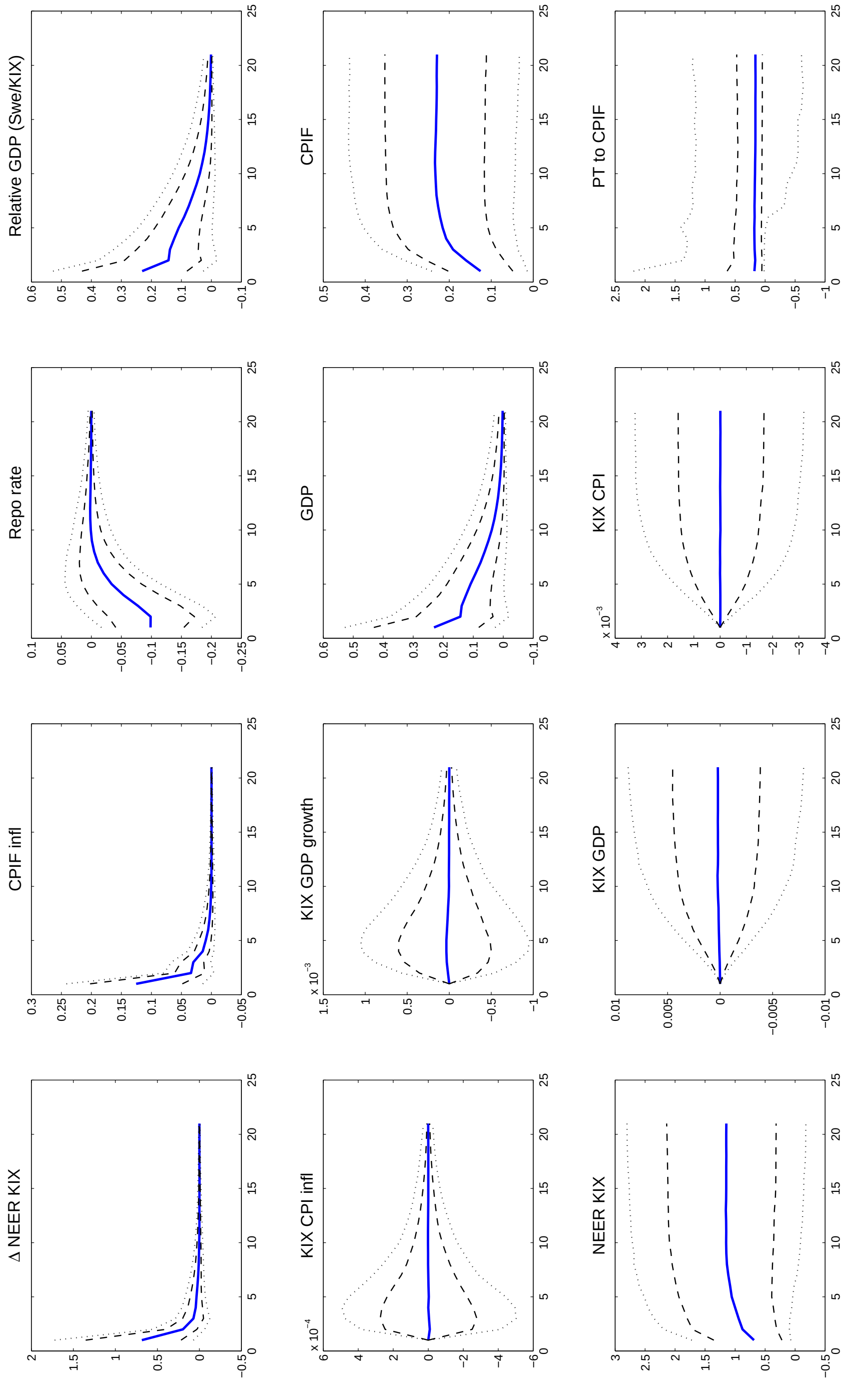

Figure B.3: Impulse responses to a Swedish monetary policy shock in the benchmark model. The graphs report the median impulse response (solid line) with the 68 percent interval (dashed lines) and the 90 percent interval (dotted lines). The responses are rescaled to cause an appreciation of the Swedish Krona by 1 percent after 4 quarters in the median case. The relative GDP is not expressed in percentage terms.

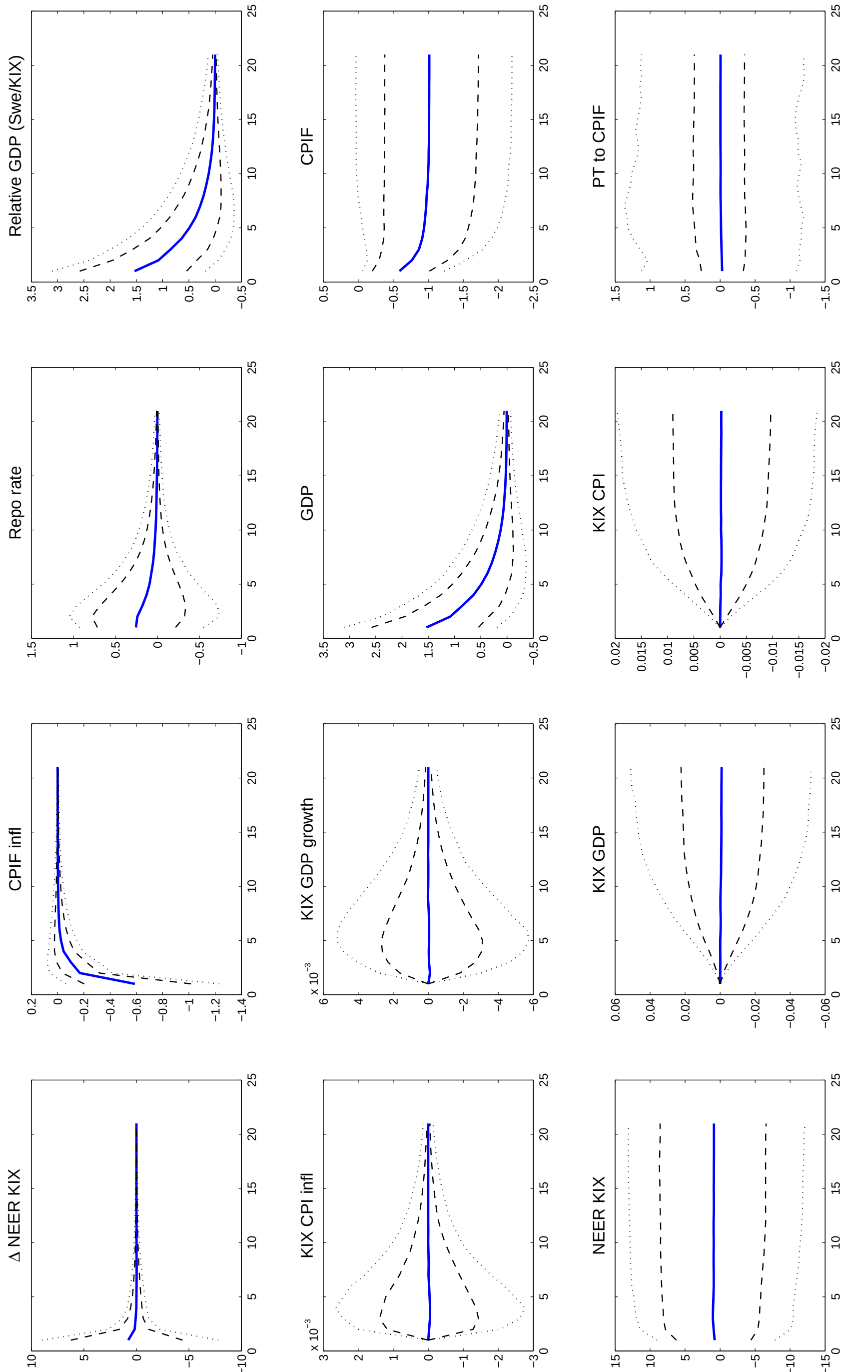

Figure B.4: Impulse responses to a Swedish supply shock based in the benchmark model. The graphs report the median impulse response (solid line) with the 68 percent interval (dashed lines) and the 90 percent interval (dotted lines). The responses are rescaled to cause an appreciation of the Swedish Krona by 1 percent after 4 quarters in the median case. The relative GDP is not expressed in percentage terms.

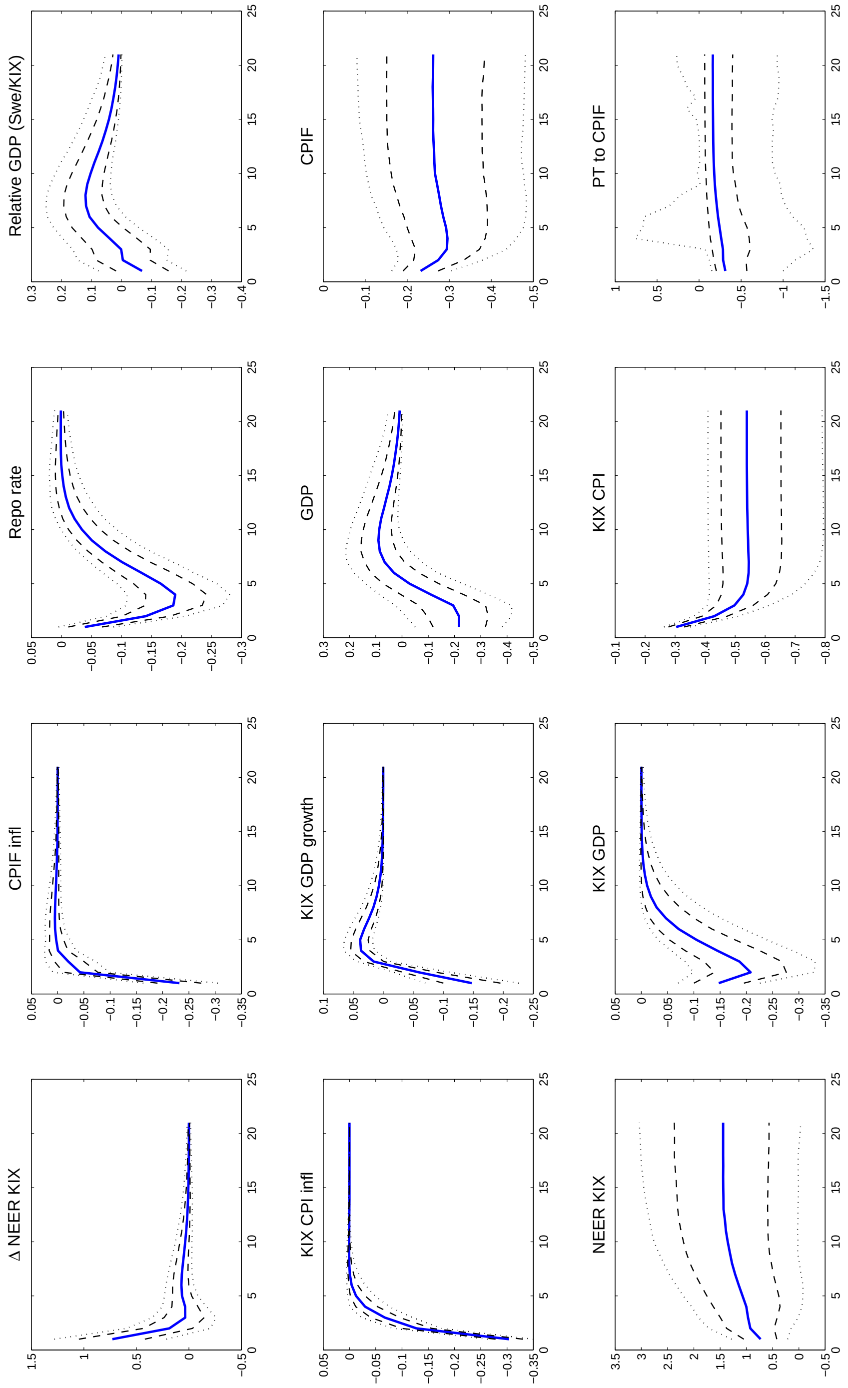

Figure B.5: Impulse responses to a global demand shock in the benchmark model. The graphs report the median impulse response (solid line) with the 68 percent interval (dashed lines) and the 90 percent interval (dotted lines). The responses are rescaled to cause an appreciation of the Swedish Krona by 1 percent after 4 quarters in the median case. The relative GDP is not expressed in percentage terms.

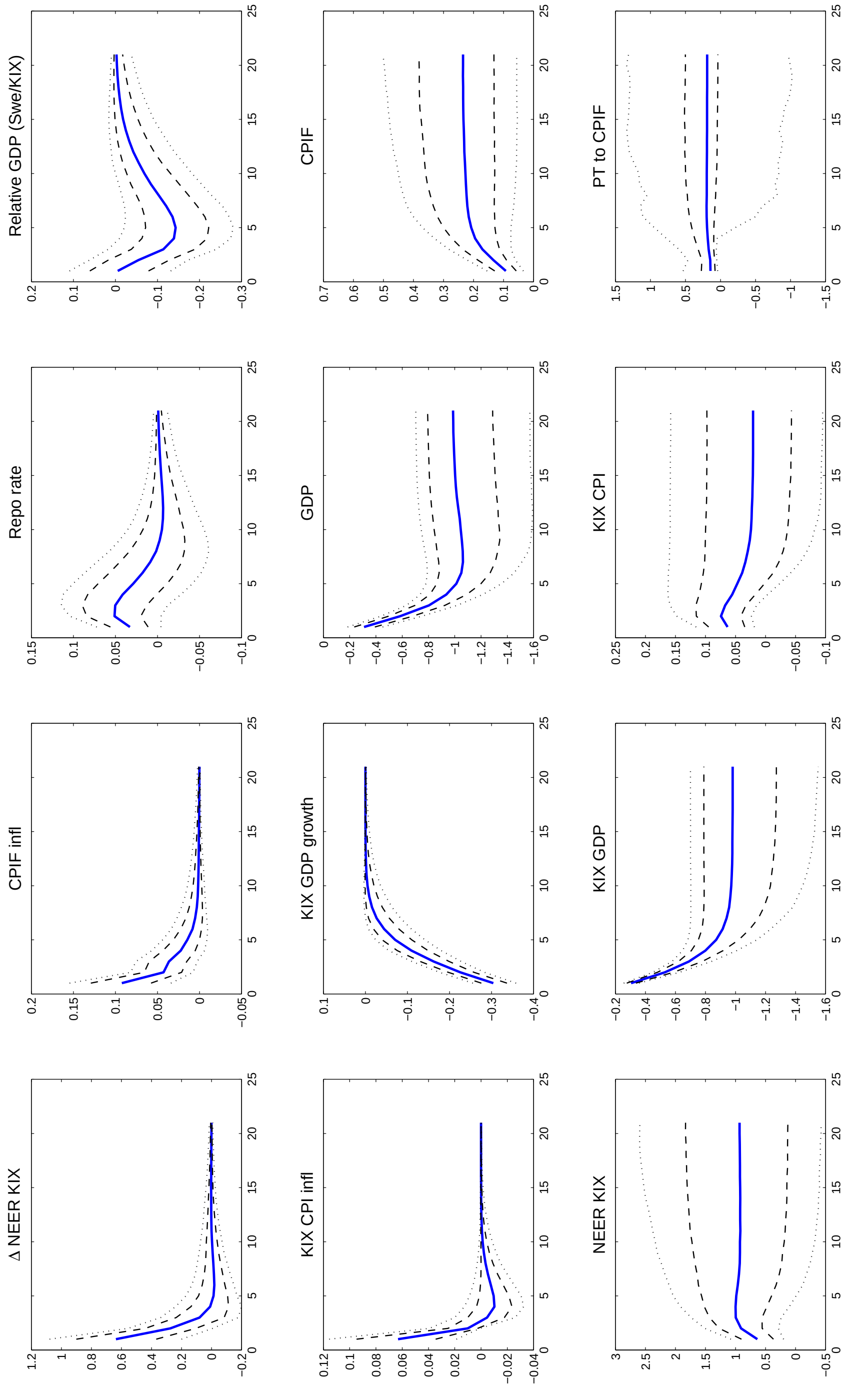

Figure B.6: Impulse responses to a global supply shock shock in the benchmark model. The graphs report the median impulse response (solid line) with the 68 percent interval (dashed lines) and the 90 percent interval (dotted lines). The responses are rescaled to cause an appreciation of the Swedish Krona by 1 percent after 4 quarters in the median case. The relative GDP is not expressed in percentage terms.

C Appendix: Historical decompositions for benchmark model

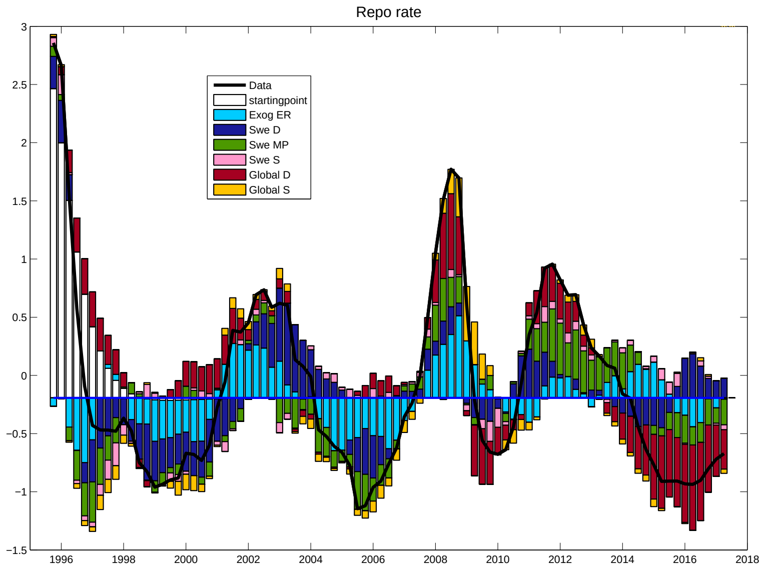

Figure C.1: Historical decomposition of the repo rate

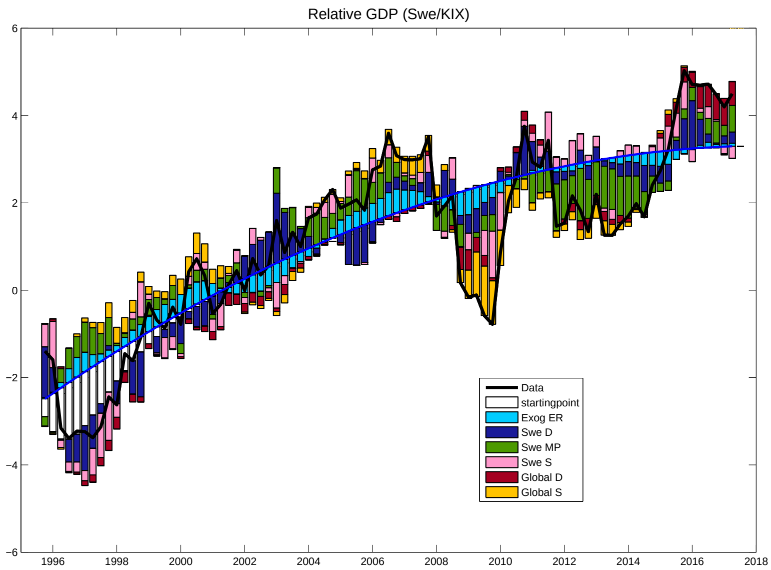

Figure C.2: Historical decomposition of relative GDP, difference from long-run trend

D Appendix: Impulse responses for alternative model

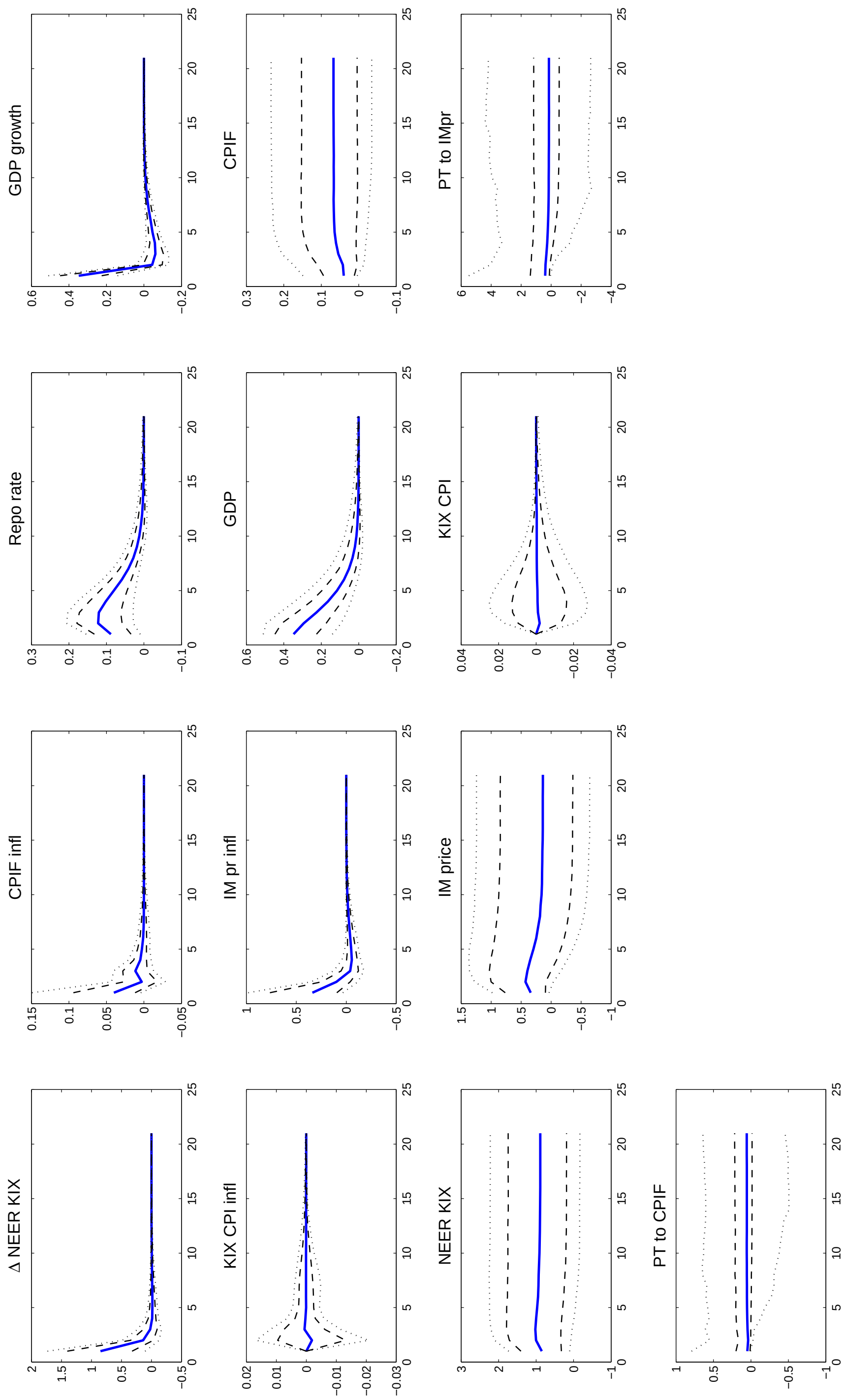

Figure D.1: Impulse responses to an exogenous exchange rate shock based on the alternative identification. The graphs report the median impulse response (solid line) with the 68 percent interval (dashed lines) and the 90 percent interval (dotted lines). The responses are rescaled to cause an appreciation of the Swedish Krona by 1 percent after 4 quarters in the median case.

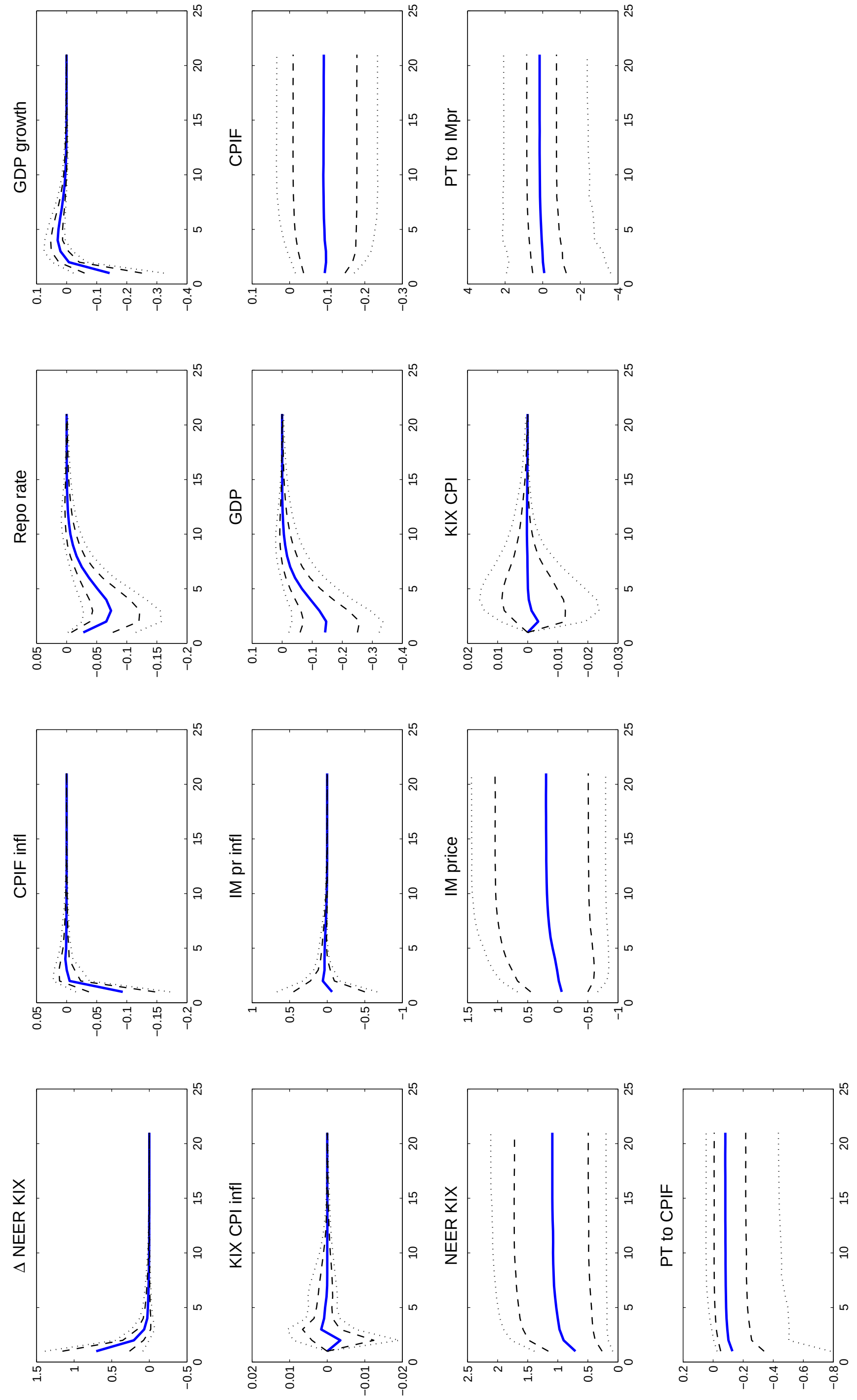

Figure D.2: Impulse responses to a Swedish demand shock based on the alternative identification. The graphs report the median impulse response (solid line) with the 68 percent interval (dashed lines) and the 90 percent interval (dotted lines). The responses are rescaled to cause an appreciation of the Swedish Krona by 1 percent after 4 quarters in the median case.

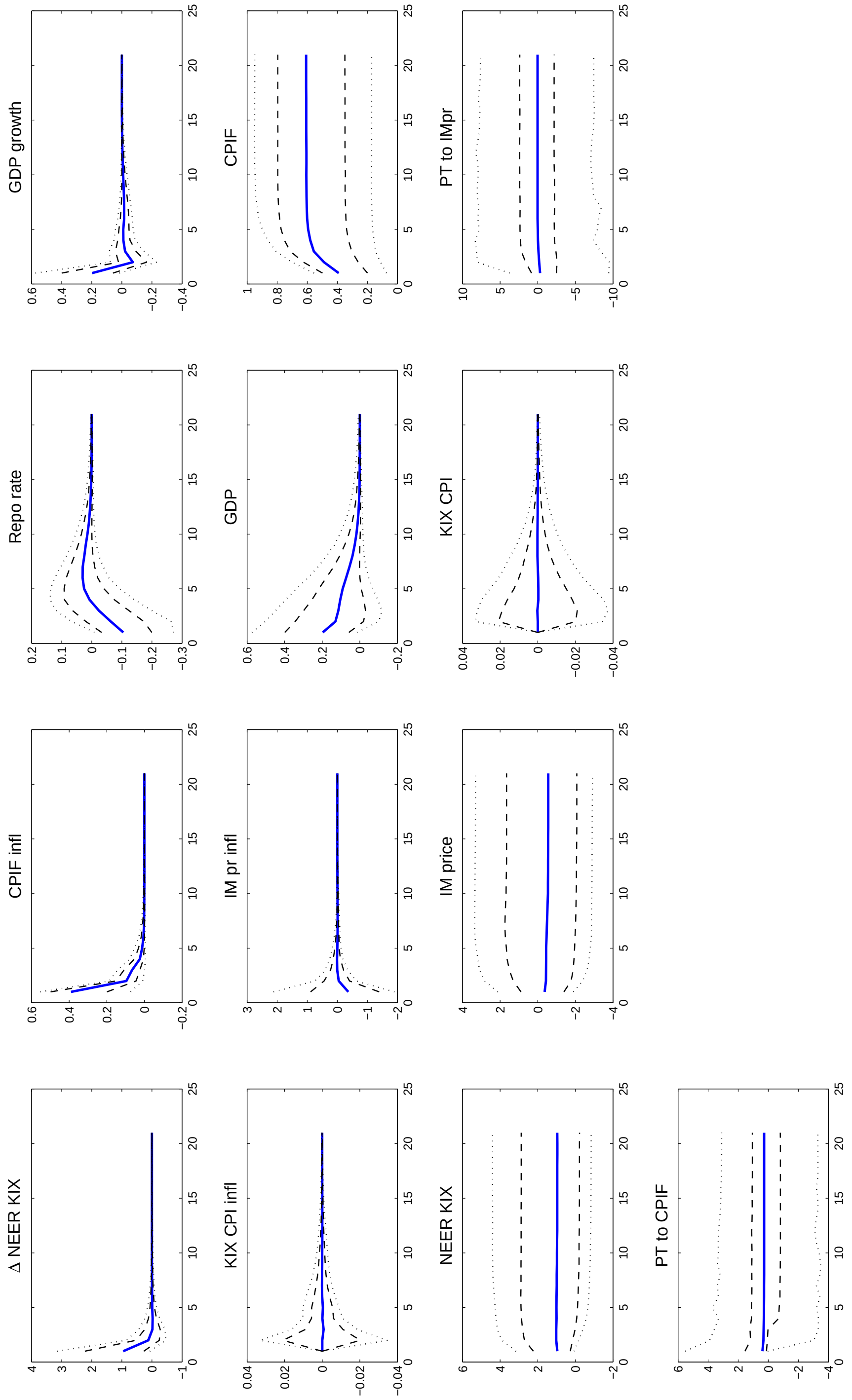

Figure D.3: Impulse responses to a Swedish monetary policy shock based on the alternative identification. The graphs report the median impulse response (solid line) with the 68 percent interval (dashed lines) and the 90 percent interval (dotted lines). The responses are rescaled to cause an appreciation of the Swedish Krona by 1 percent after 4 quarters in the median case.

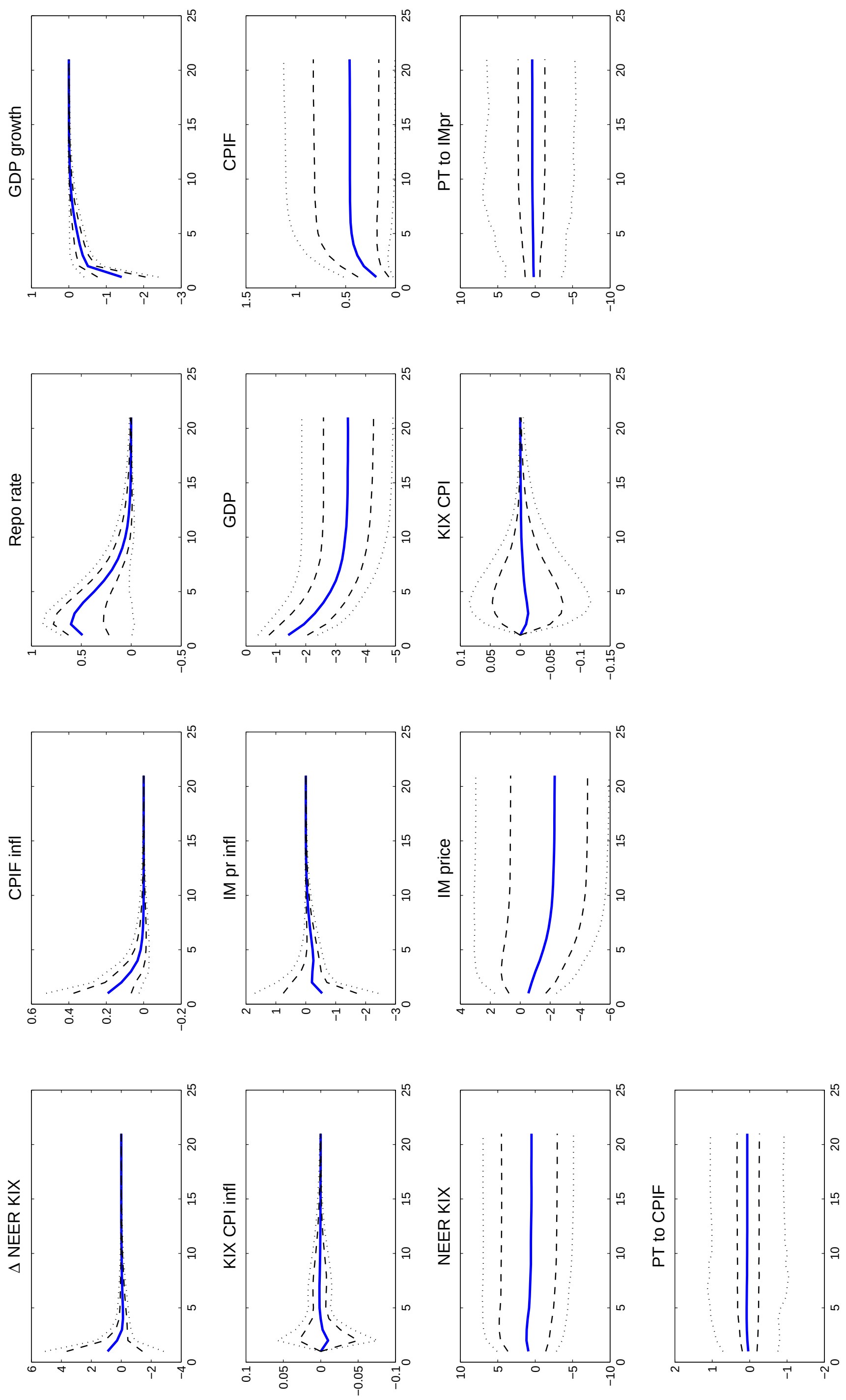

Figure D.4: Impulse responses to a Swedish supply shock based on the alternative identification. The graphs report the median impulse response (solid line) with the 68 percent interval (dashed lines) and the 90 percent interval (dotted lines). The responses are rescaled to cause an appreciation of the Swedish Krona by 1 percent after 4 quarters in the median case.

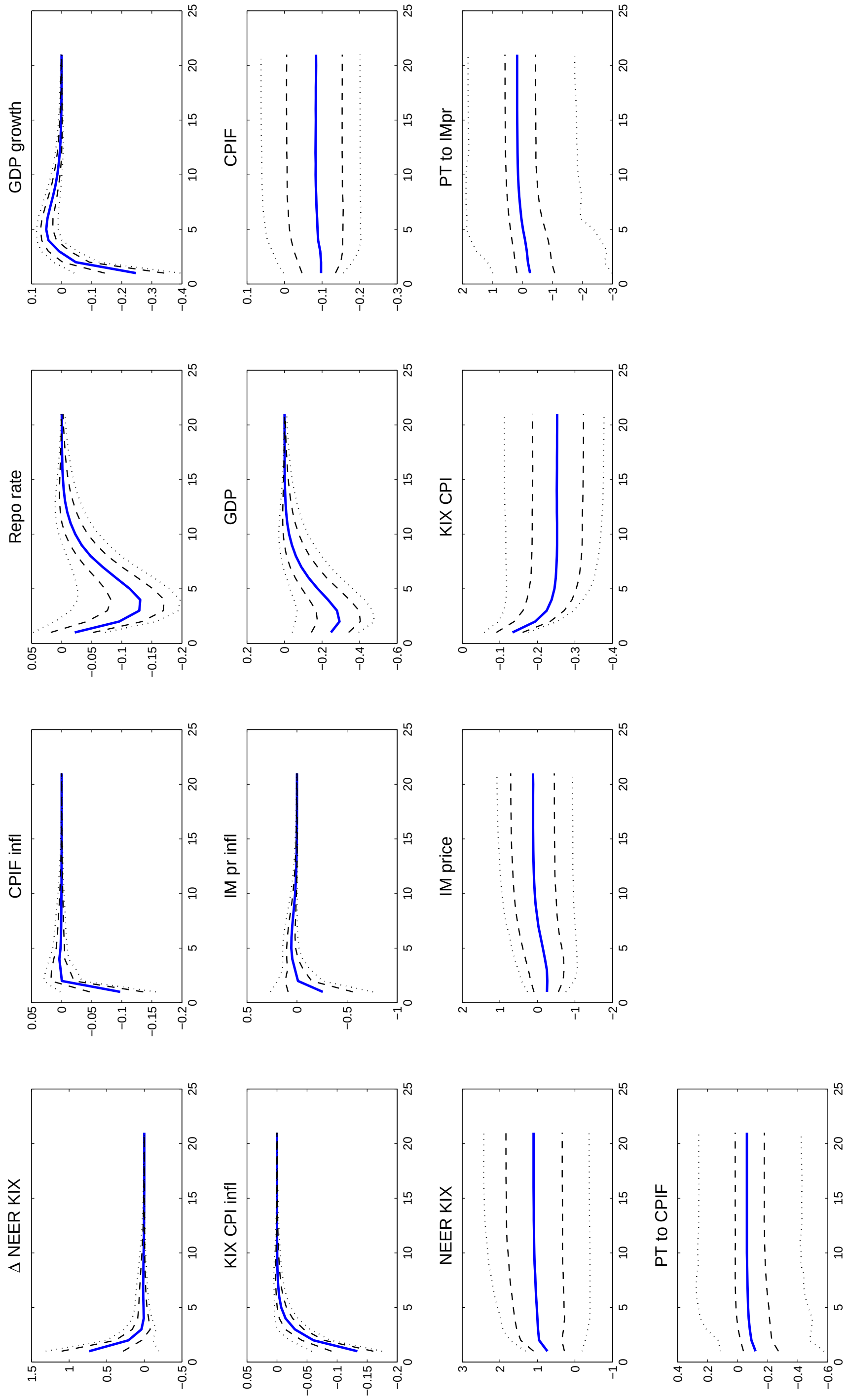

Figure D.5: Impulse responses to a global demand shock based on the alternative identification. The graphs report the median impulse response (solid line) with the 68 percent interval (dashed lines) and the 90 percent interval (dotted lines). The responses are rescaled to cause an appreciation of the Swedish Krona by 1 percent after 4 quarters in the median case.

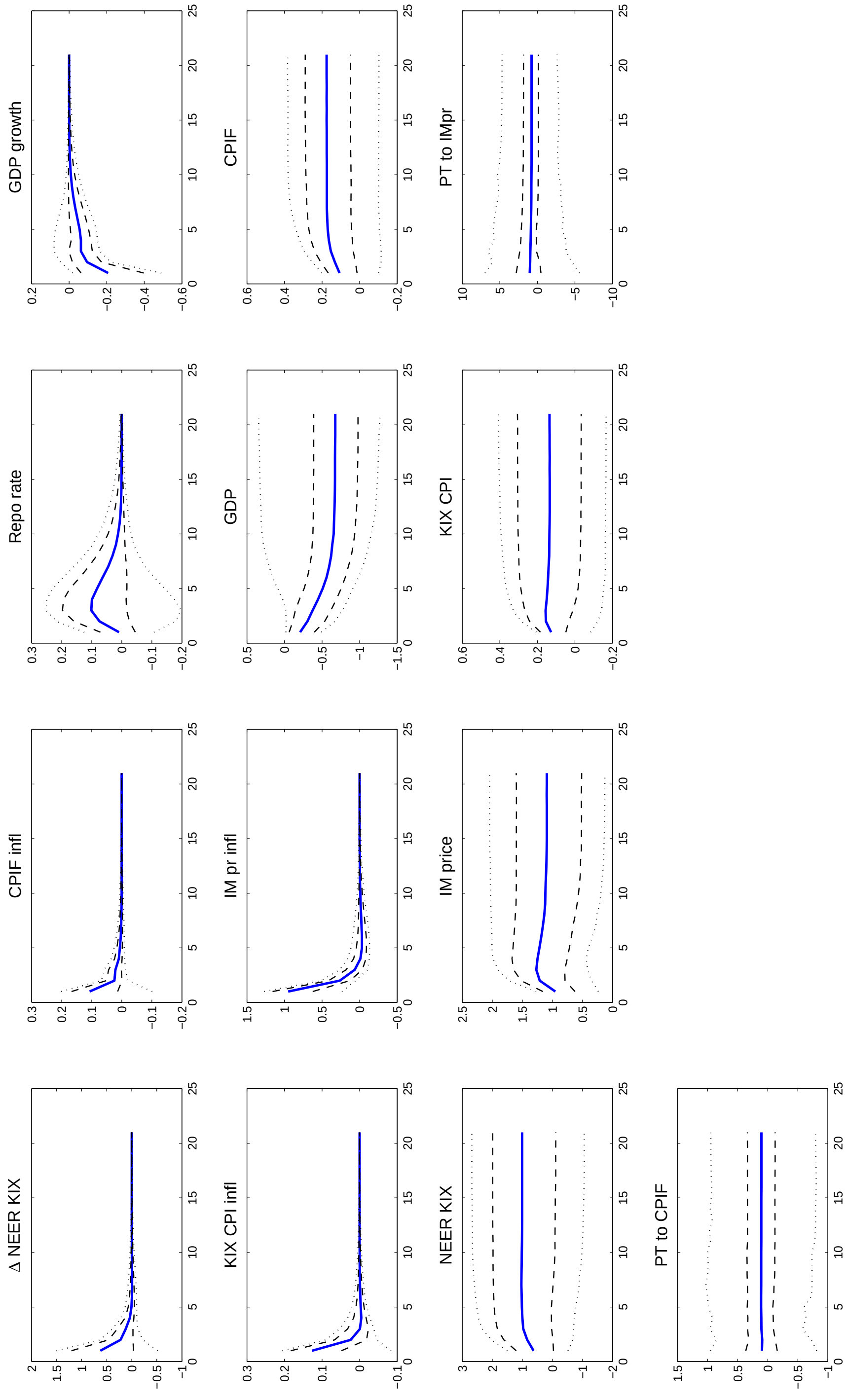

Figure D.6: Impulse responses to a global supply shock based on the alternative identification. The graphs report the median impulse response (solid line) with the 68 percent interval (dashed lines) and the 90 percent interval (dotted lines). The responses are rescaled to cause an appreciation of the Swedish Krona by 1 percent after 4 quarters in the median case.

E Appendix: Historical decompositions for alternative model

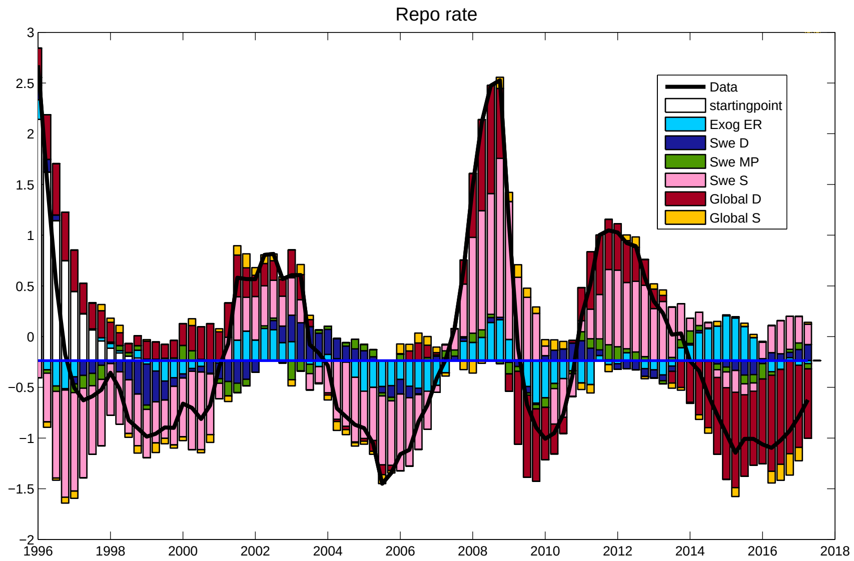

Figure E.1: Historical decomposition of the repo rate

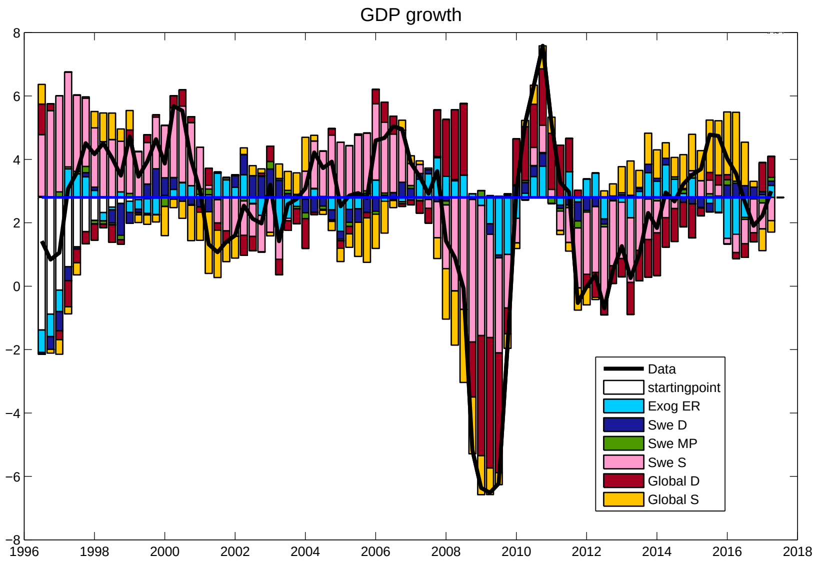

Figure E.2: Historical decomposition of GDP, year-on-year changes