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Drivers of consumer prices and exchange rates in small open economies*

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Abstract

We study the fluctuations of exchange rates and consumer prices in two small open economies, Sweden and Canada, using a structural Bayesian VAR. Four domestic and two global shocks are identified through zero and sign restrictions. For both economies, we find that the main driver of consumer price inflation is the global demand shock. A negative global demand shock is not only deflationary for the small open economy, but also depreciates its currency. Hence, the observed exchange rate pass-through following this shock is of opposite sign to what is usually expected. Finally, exogenous shocks to the exchange rate are less important drivers of exchange rate movements than in many other structural models.

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

JEL classification: E31, E52, F31, F41.

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1 Introduction

The implications of exchange rate fluctuations for the economy depend on their underlying causes. For example, if the exchange rate appreciates due to 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, which may be further strengthened by a substitution away from domestically produced goods towards imported goods. If, instead, the exchange rate appreciates due to a positive demand shock, the net effect on inflation is not clear ex ante. On one hand, there is a downward pressure on aggregate inflation from lower import prices. On the other hand, there is also an upward pressure on inflation due to the increased demand for all goods. The net effect will depend on which factor has a larger impact.

Motivated by this reasoning, we estimate structural VAR models with Bayesian techniques and study the comovement between the exchange rate and final consumer prices, conditional on the shock driving the economy. We focus on two small open economies with inflation targeting central banks: Sweden and Canada. Gauging from the high share of imports invoiced in a foreign currency (between 70 and 80 percent), inflation in Canada and Sweden is highly sensitive to exchange rate fluctuations.[1] Given their high trade openness, we pay particular attention to the identification of global shocks.[2] Overall, we identify six structural shocks – four domestic and two global – with zero short-run and long-run restrictions and sign restrictions. We compute the pass-through to prices following each of the identified shocks, as well as a measure of average pass-through to prices.

It is not uncommon to use "rules of thumb" to assess the degree of price change after exchange rate fluctuations. Rules of thumb assume a positive exchange rate pass-through, meaning that currency depreciations (appreciations) bring about increases (decreases) in consumer prices. However, to the extent that different shocks drive the exchange rate and prices in different ways, the pass-through may not only differ substantially according to the shock, but also have a different sign than what is usually expected. Here we find that the pass-through from exchange rate movements to consumer prices has the opposite sign after global and domestic demand shocks.

[1]These figures are taken from Gopinath (2015) and are averages for the period 1999-2014.

[2]Over the period 1995-2019, the average share of imports and exports over GDP – the index of trade openness – for Sweden and Canada is equal to 82 percent and 69 percent, respectively. The same index equals 50 percent for OECD countries and 26 percent for the US.

Currency depreciations (appreciations) are associated with a decrease (increase) in prices. Global demand shocks not only feature a reverse-sign pass-through, but they also turn out to be the main driver of consumer price inflation in small open economies. Finally, in our model demand and supply shocks explain most of the variation in exchange rates, unlike in other structural models.

There is a large literature on exchange rate pass-through and its determinants.[3] There are, however, fewer studies linking the pass-through to the drivers of the exchange rate fluctuations. Corsetti and Dedola (2005), Corsetti et al. (2008) and Bouakez and Rebei (2008) are among the most prominent examples of micro-founded models that highlight the different exchange pass-through to import and consumer prices, depending on the shock affecting the economy. The authors also show that a negative (reverse-sign) pass-through is possible, following specific shocks, due to general equilibrium effects. On the empirical side, Shambaugh (2008) uses a structural VAR model identified with long-run restrictions for a set of 16 countries to derive the exchange rate pass-through to consumer and import prices. In this sense, the paper is an important first step in improving our understanding of shock-dependent exchange rate pass-through empirically. More recently, Forbes et al. (2018) propose a structural VAR model 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 has been used used for the Euro area and four member states (Germany, France, Italy, and Spain) by Comunale and Kunovac (2017). Forbes et al. (2017) modify the original approach from Forbes et al. (2018) in order to estimate the exchange rate pass-through by shock for 26 developed and emerging economies. They study its variation across time and economic structure. With a similar aim, Ha et al. (2019) study 29 advanced and 26 non-advanced economies with a FAVAR model, where shocks are identified with zero short-run and sign restrictions.[4]

Our contribution to this literature is both methodological and quantitative. On the methodological side, we provide a tractable identification of global demand and supply shocks for the structural VAR model of a small open economy. We are espe-

[3]Few prominent examples are Taylor (2000), Bacchetta and Van Wincoop (2003), Gagnon and Ihrig (2004), Campa and Goldberg (2005), Gopinath et al. (2010) and Auer and Schoenle (2016). See Burstein and Gopinath (2014) for a literature review.

[4]A different approach to modelling shock-dependent exchange rate pass-through is used in Cunningham et al. (2017). Using instrumental variables techniques, they study the exchange rate pass-through to import prices after various US demand-like shocks and oil price shocks for 7 advanced economies.

cially interested in identifying the global shocks appropriately, since we study small and very open economies, where global shocks have great influence. Indeed, Aastveit et al. (2016) show that world and regional shocks, on average, contribute to more than 50 percent of fluctuations of small open economies (Canada included). According to recent studies, the role of shocks originating abroad for the business cycle of individual economies has increased in the last years (Fernández et al. (2017), Miyamoto and Nguyen (2019)). In the literature, Forbes et al. (2018) and similar studies distinguish between persistent and temporary global shocks, having only foreign prices (import and export prices) in the model. Instead, Ha et al. (2019) rely on global factors in a FAVAR model with zero short-run and sign restrictions to distinguish global shocks. The distinctive feature of our paper is to provide identifying restrictions for global demand and global supply shocks within an open-economy VAR model, where the foreign economy is represented by the each country's most important trading partners. With respect to the aforementioned literature, our restrictions ensure that global demand shocks are temporary, while global supply shocks are permanent.[5] As a confirmation of their global nature, we find our global shocks to be positively correlated across the estimated models for Sweden and Canada. In particular, the global demand shock displays a correlation of 0.8 between the two models.

Both for Sweden and Canada, we find that the lion's share of exchange rate fluctuations is explained by the exogenous exchange rate shock. This shock generally features a small pass-through, around 5 percent, and explains at most around 20 percent of the fluctuations in the effective exchange rate. In line with the aforementioned VAR literature, our model shows less "exchange rate disconnect" than usually found in DSGE models.[6] On average, the pass-through is found to be around zero, but it varies substantially by shock. In line with the literature, the highest pass-through to domestic consumer prices is found for monetary policy or global supply shocks, for which is as high as $10-15$ percent. The pass-through is negative when the economy is hit by domestic and, especially, by global demand shocks. In other words, a 1 percent appreciation of the exchange rate brought about by stronger demand is accompanied by an increase rather than decrease in consumer prices by 5 to 10 percent, if local, and 20 to 30 percent, if global.[7] After demand shocks, the upward pressure

[5] In section 5 we provide results with alternative identification schemes, similar to the ones proposed in the literature, showing the distinctive benefits of our restrictions.

[6] The "exchange rate disconnect puzzle", so called by Obstfeld and Rogoff (2000), refers to the weak relationship between the exchange rate and other macroeconomic variables. DSGE models usually assign a large share of the variation in the exchange rate to exogenous risk premium shocks (Justiniano and Preston, 2010b).

[7] Note that we here refer to deviations from long-term trends, and so our results regarding the

on prices stemming from increased demand thus dominates the effect of exchange rate movements on producers' costs.[8]

While a negative pass-through is found also in the other studies following the domestic demand shock, a key feature of our analysis is to find it negative even after *global* demand shocks. Indeed, in absolute terms, the global demand shock features the largest pass-through. This shock turns out to be the main driver of domestic inflation of the small open economies, unlike what is usually found in the literature. Our results are especially interesting, because they help us understand the behaviour of inflation in Sweden and Canada during a recent period of large currency depreciations. In both countries, inflation was low between 2012 and 2014 (2015 in the case of Sweden), at the same time as the exchange rate was on a depreciating trend. Inflation in Sweden remained low because the currency depreciation was mostly due to negative domestic and global demand shocks, that exerted a downward pressure on prices. In Canada, inflation remained subdued because the currency depreciation stemmed mostly from positive exogenous exchange rate shocks, with small pass-through, and negative demand shocks, with a negative pass-through.

The rest of the paper is organized as follows. Section 2 describes the data and the model, together with a definition of conditional exchange rate pass-through. Section 3 and 4 report our results for Sweden and Canada, respectively. Section 5 presents the robustness analysis. Section 6 discusses the common findings across Sweden and Canada and section 7 concludes.

2 Model

In this section we describe the data used, the estimated BVAR model and the strategy for shock identification.

2.1 Data

We run our estimation on data for Sweden and Canada, covering their inflation targeting period. All series are quarterly and, as some series are included in first differences, our sample covers the period 1995q2-2017q2. The series included in our benchmark specification are: domestic GDP, consumer prices, policy rate and exchange rate, as well as foreign consumer prices and GDP. The domestic GDP enters

price changes and levels should be interpreted as deviations from the average inflation in our sample.

[8] This could reflect the use of pricing-to-market strategies by price setters.

in relative terms with respect to the foreign GDP. All series, except the policy rate and the relative GDP, are measured in terms of quarterly log differences.

Consumer prices are measured as the rate of inflation of CPI for Canada and CPIF for Sweden.[9] The interest rates we use are the target rate for Canada and the repo rate for Sweden. The monetary policy measure used is the gap between the policy rate and a time-varying interest rate trend. Over our sample interest rates in Sweden and Canada, similarly to the rest of the world, have consistently trended downwards. We treat this trend as an exogenous change in the global (real) rate, and thus remove it prior to our estimation. The time-varying interest rate trend is measured either with the HP filter (Canada, Sweden) or a DSGE-based measure of neutral rate (only Sweden).[10] The exchange rate is the nominal effective exchange rate (KIX) index, computed using competition-based weights, for Sweden, while we use the bilateral CAD/USD exchange rate for Canada.[11] In both cases, an increase in the exchange rate implies a depreciation and a decrease an appreciation of the local currency. The reason for the different choice of the exchange rate comes from the weight of the two countries' trade partners. The main trading partner for Sweden, the Euro Area, has a weight equal to 46 percent. Instead, the US represents 75 percent of trade for Canada. Therefore, we need to include more trade partners for Sweden. The correlation between Swedish and KIX-weighted GDP is around 0.9, compared to 0.8 for Canada and US. In terms of inflation, the correlation between Sweden and the foreign economy is 0.5, compared to 0.7 for US and Canada. Given the different choices of exchange rates and for consistency reasons, foreign consumer prices and foreign GDP are measured as weighted averages of the main trading partners, using the KIX weights, for Sweden, and with US data for Canada.

[9] CPIF is the consumer price index inflation with the mortgage rates held fixed. The CPIF has been the Riksbank's operational target variable for several years and it also became the formal inflation target variable for monetary policy as of September 2017.

[10] For Sweden, the neutral rate is estimated in the Riksbank's DSGE model, Ramses II (Adolfson et al., 2013). The specification of the neutral rate is inspired by the model in Laubach and Williams (2003). Estimates of this neutral rate are available upon request. We note also that the policy rate for the case of Sweden 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 5.1, using a measure of monetary policy that contains also the effects of asset purchases, the shadow interest rate.

[11] The KIX index refers to an aggregate of countries that are important for Sweden's international transactions, in terms of imports, exports and third-country effects. 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/.

2.2 Estimation

We estimate the VAR models in first differences, except for the interest rate and the relative GDP, which are included in levels, with 2 lags, using Bayesian methods. The choice of taking the variables in first difference is driven by the use of zero long-run identifying restrictions, requiring the system to be stationary. We use the methodology laid out in Villani (2009), that also requires stationarity, and hence the VAR model is written in deviation from 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.[12] Arias et al. (2014) prove that their algorithm, unlike other algorithms proposed in the literature, does not impose additional restrictions, apart from the identifying ones. The reported results are based on 1000 draws, after we have discarded the initial 100.

2.3 Identification

Using the series described above, we identify the following six structural shocks: shocks to local and global demand, shocks to local and global supply, a local 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 main difference with the empirical literature on shock-dependent exchange rate pass-through - started with Forbes et al. (2018) - is that we provide an identification that disentangles global demand from global supply shocks. We are able to do so in a tractable way, because our model contains not only foreign prices, but also foreign GDP. In fact, the domestic GDP enters the model in relative terms with respect to the foreign GDP.

The restrictions we use are summarized in Table 1. As Sweden and Canada are small open economies, of a size negligible to the global economy, we assume that domestic shocks can have no effect on global variables. Domestic 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 domestic shocks on the foreign variables is restricted to be null. Hence, we do not need to impose any zero long-run restrictions from the domestic shocks to the foreign variables. The identification of the specific domestic shocks is then based on

[12]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 exogenous variables as $\lambda_4 = 0.01$, due to the assumption of a small open economy.

sign restrictions. These are generally imposed on impact, meaning the quarter when the shock hits (unless otherwise mentioned).

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

Table 1: Identifying restrictions for the benchmark model. The signs on the diagonal are included in the table for clarity, and are only there for normalization purposes. The sign restrictions are imposed for 1 quarter following the shocks, except the case of the global supply shock, where the (-) sign restriction is imposed for 2 quarters following the shock.

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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 the work by Blanchard and Quah (1989). Note, however, that we include two GDP series in the model – one for the domestic and one for the foreign economy. We replace the domestic GDP with relative domestic GDP, measured as the quarterly log difference of the two rescaled series. In this way we assume co-integration between domestic and foreign GDP, implying that the two series co-move in the long run. We then need to impose zero long-run restrictions only for the foreign GDP, as those for the domestic one will be implicit. This choice implies a reduced set of zero long-run restrictions, making the identification more tractable. It also implies that only the global supply shock is allowed to have permanent effects on domestic 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 DSGE models of small open economies, 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. 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 domestic and the foreign economies, we introduce a quadratic trend at the steady state, that is estimated together with the other parameters.

Moving on to the sign restrictions, the domestic supply (or cost-push) shock is assumed to move domestic GDP and consumer price inflation in opposite directions. The domestic demand shock is assumed to move domestic GDP and 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.[13] A monetary policy shock implying an increase in the interest rate is assumed to have a negative effect on domestic GDP and consumer price inflation, and to bring about an appreciation in the exchange rate on impact.

The shock to the nominal exchange rate is restricted to cause an increase in domestic 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 uncovered interest rate parity (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.[14] Note that this shock is domestic, in our model as in standard small-open economy DSGE models, and is not allowed to have any effect on foreign variables. It is thus a financial or risk shock specific to the domestic economy and the domestic

[13]In Section 5 we show that our results are not sensitive to relaxing the sign restriction of the response of the exchange rate.

[14]For example, it could 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. See Itskhoki and Mukhin (2017) for further details and for references to studies exploring each of the listed interpretations.

currency, and not a shock affecting financial markets globally. It is possible that some global financial shocks could have effects on the domestic currency over and above those going through trade channels, and that one should interpret also those as shocks specific to the exchange rate. 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.[15] 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.[16]

Our model does not include a measure of the foreign interest rate, implying that we do not identify a foreign monetary policy shock. We know from earlier VAR studies that monetary policy shocks play a rather small role in driving the business cycle (see Christiano et al. (1999) for early evidence), and should as such not be amongst most important drivers of spillovers from a big to a small open economy. We thus note that foreign monetary policy shocks will be captured by the global demand shock in our setting. In addition, in our model shocks to commodity prices, such as oil price shocks, may be captured by global shocks, in particular the global demand shock. Shocks to commodity prices are especially important for Canada, that is the fifth largest oil producer in the world, whereas most of the oil exported goes to the US.[17]

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

[15]Note that the price response of foreign inflation is normalized to be positive following the shock to global supply, due to the ordering of the variables in our model. Hence, all the elements on the diagonal of the upper matrix in Table 1 are set to a plus by assumption, and thus the restriction we need to impose on GDP is negative.

[16]In addition, in Appendix C we show that the responses to the global shocks are very imprecisely estimated if we use the same model and identification strategy as in Forbes et al. (2018) for the Swedish case, distinguishing global persistent from global temporary shocks.

[17]An analysis of the importance of energy prices for the CAD/USD exchange rate is provided in Issa et al. (2008) and Charnavoki and Dolado (2014).

movements in the global economy spill over to the domestic economy and what the responses of the domestic 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.

2.4 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.[18]

3 Results for Sweden

Here we report the results from the BVAR model estimated on Swedish data, where the policy rate is detrended with our measure of neutral rate. However, results are similar if we detrend it with an HP filter, as done for Canada.

Having identified the six shocks discussed in the previous section, we can now disentangle their relative importance in explaining the fluctuations in the nominal exchange rate and prices across time.[19] We first present the forecast error variance

[18] This is not the traditional definition of pass-through, usually captured in univariate regression models between inflation and the exchange rate (Burstein and Gopinath, 2014), even though it has become increasingly common in the literature. Our definition is common to Shambaugh (2008) and Forbes et al. (2018), among others, and highlights the existence of different drivers of exchange rate fluctuations.

[19] The impulse response functions are reported in Figures A.1 - A.6 in Appendix A. Note that they have been rescaled so as to generate a one percent depreciation of the Swedish Krona after 4 quarters. Since the calculation of the CERPT requires the impulse responses of prices and exchange

decomposition of the exchange rate and inflation, and then discuss the historical decomposition of two variables. The rest of the section is devoted to the analysis of the pass-through from the exchange rate to inflation, depending on the shock hitting the economy.

3.1 Decompositions

Table 2 presents the share of the exchange rate and inflation forecast error variance that is explained by each of the six identified shocks at the 8-quarter horizon.[20] The share of the exogenous exchange rate shock is 22 percent. In our specification, 20 percent of the Swedish Krona movements is explained by global shocks and 58 percent is due to the three domestic shocks, excluding the shock to the exchange rate. The domestic demand shock features the highest share, equal to 32 percent.[21] It is interesting to note that the exogenous exchange rate shock, which is the one responsible for most of the exchange rate variations in small open economy DSGE models, accounts for a rather limited share of exchange rate movements. These results point to the limitations of the analysis of exchange rates in that type of models.[22]

On the other hand and differently from the related literature, CPIF inflation is mostly explained by the global demand shock, that features the highest share at 31 percent. Taken together, global shocks account for almost half of the variation in CPIF inflation. The comparison with the nominal exchange rate reveals that domestic shocks are more important for the exchange rate and global shocks are more important for inflation.

	Exog ER	Swe D	Swe MP	Swe S	Global D	Global S
NEER	22	32	13	13	9	11
Inflation	12	13	12	18	31	14

Table 2: Forecast error variance decomposition (FEVD) of the the nominal effective exchange rate and CPIF inflation for Sweden. The numbers represent percentages of the forecast error variance due to each shock.

rate in levels, we report the IRFs with probability bands also for the cumulated price indices and the cumulated change in the exchange rate. Moreover, we report the domestic and foreign GDP in levels.

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

[21]This result is in contrast to Forbes et al. (2017) and Ha et al. (2019), who find the monetary policy shock to be the main driver of exchange rate movements.

[22]See, for example, Justiniano and Preston (2010a) and Ca' Zorzi et al. (2017) for problems of exchange rate modelling in DSGE models.

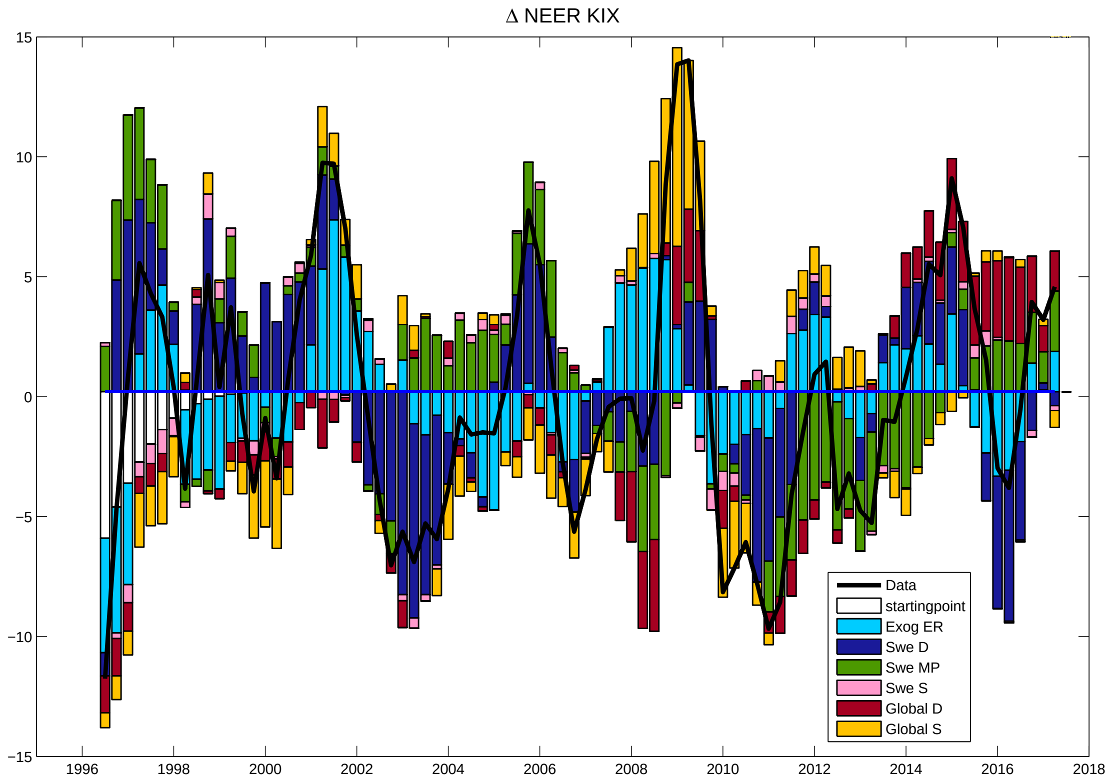

Figure 1: Historical decomposition of the the nominal effective Swedish krona exchange rate, year-on-year changes.

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 main drivers of 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 financial crisis, the Krona underwent the largest depreciation of the last two decades, which 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 global financial markets. The financial crisis was mostly an imported phenomenon for a small open economy like Sweden. We note that, in contrast to our findings, the results for Sweden in Forbes et al. (2017) indicate that the

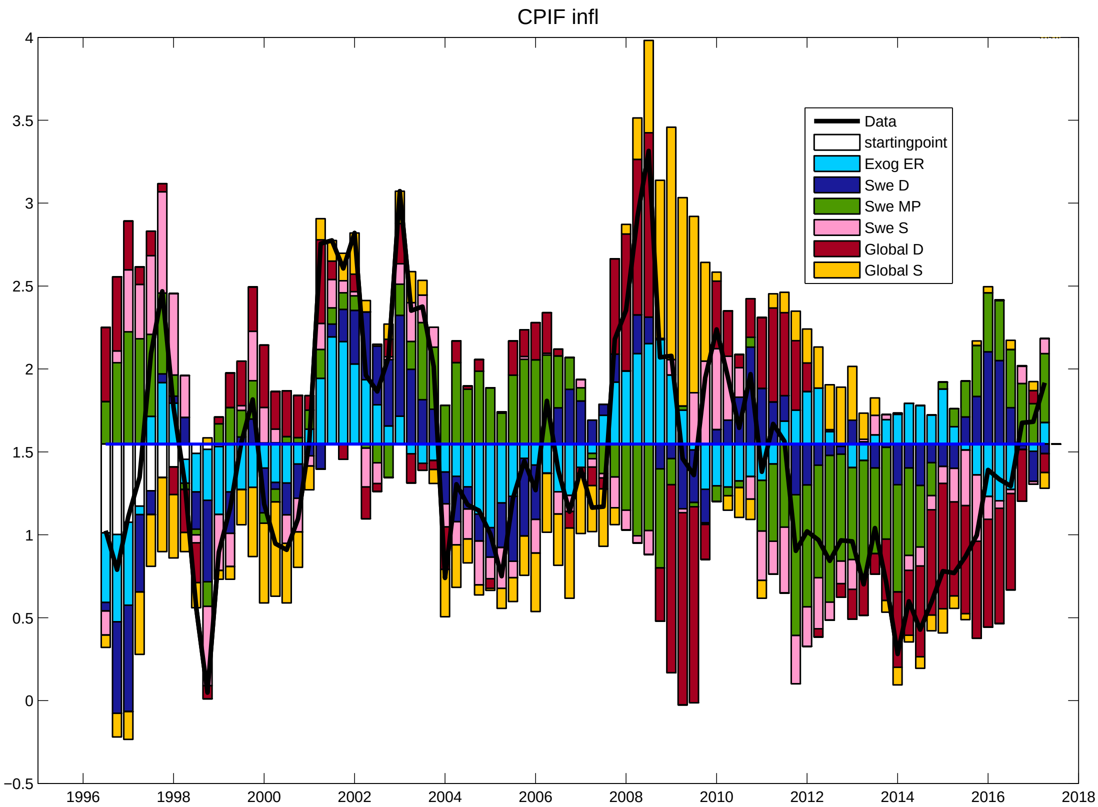

Figure 2: Historical decomposition of the the Swedish CPIF inflation, year-on-year changes.

development during the crisis was largely due to Swedish demand shocks. However, the scope for comparison is limited, since the authors use a different measure for inflation and the exogenous exchange rate shock is not accounted for.

In 2013 another sizeable depreciation of the Krona started, this time driven largely by negative contributions from monetary policy shocks. The weak global and domestic demand and, to some extent, the exogenous exchange rate shocks also contributed. Finally, from Figure 1 we can see that the most recent depreciation was due to disappearing positive local demand shocks in combination with negative global demand shocks and expansionary 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 the monetary policy shock. 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 low inflation at the same time as the Krona was depreciating. As we 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 inputs 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, that was accompanied by a weak Krona.

3.2 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 2.4, 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.[23]

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 to eight quarters but 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. 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.[24]

The highest positive pass-through is obtained following the global supply and the

[23] As we can see from the figures of impulse responses in Appendix A and B, in most cases the sign of the 68 percent probability bands coincides with the sign of the median ratio and does not contain zero.

[24] 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 period ahead also to the impact responses.

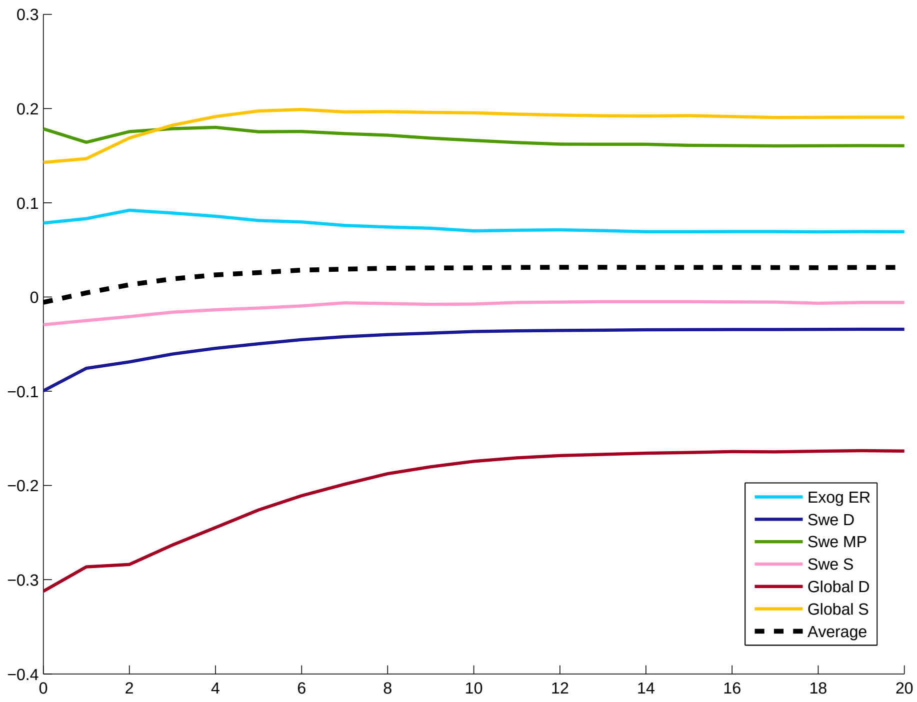

Figure 3: Exchange rate pass-through to CPIF by shock and on average across 20 quarters, for the benchmark model in Sweden

monetary policy shocks. The global supply shock features a pass-through, close to 15 percent in the short and 20 percent the long run. The impulse responses show that it has rather large effects on inflation, which are only partly offset by monetary policy, since output moves in the opposite direction (Figure A.6 in Appendix A).

The monetary policy shock features a pass-through just above 15 percent across all horizons. After a negative shock to the repo rate, firms face higher demand, since the expansionary monetary policy stimulates the economy. The demand effect allows them to increase prices. Moreover, they face higher costs for foreign inputs due to the depreciation of the Krona and transfer (some of) the increase in costs to the consumers. Both of these factors lead firms to increase consumer prices (Figure A.3 in Appendix A). Comparing our results to the ones obtained in the literature, we find that the monetary policy shock features the largest or second-largest CERPT to consumer prices in those as well. In Forbes et al. (2017) and Ha et al. (2019), the monetary policy shock is the only shock to generate a positive pass-through for all the countries analysed, with a median across countries of around 20 to 30 percent after one/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 reduce their price increases (relative to steady state). Note that, for the domestic demand shock, the negative pass-through is imposed only on impact through the sign restrictions summarized in Table 1. 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. In Forbes et al. (2018), Comunale and Kunovac (2017) and Forbes et al. (2017) global temporary and persistent shocks feature a very high and positive pass-through for UK, while results are mixed for other countries, with the median value around zero. Global demand shocks feature a pass-through close to zero also for the median of countries analysed in Ha et al. (2019). The reason for this difference is clear from the impulse response function to the global demand shock (Figure A.5 in Appendix A). A negative global demand shock that depresses inflation and output abroad is found to depreciate the local currency. As we show in the next section with Canadian data, this result is not specific to Swedish data. 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.[25] More than a third of the observed movements in the exchange rate may thus be accompanied by movements in inflation of the opposite

[25] 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. 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 comparisons with their findings.

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 impulse responses of the repo rate and the exchange rate contain zero (Figure A.4 in Appendix A) 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.

We find the average pass-through to consumer prices around zero in the long run. However, from the above results, we gain some understanding about how misleading it can be to consider a rule-of-thumb for the exchange rate pass-through to consumer prices based on an average value or on reduced-form estimates of exogenous exchange rate shocks. For example, the historical decomposition of nominal KIX exchange rate and CPIF inflation above revealed that the negative global demand shock was the major driver of the Krona depreciation during the period 2013-15. 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 depreciating 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 the low inflation developments coming from the weak global demand.

4 Results for Canada

In this section we discuss the shock decompositions and the conditional exchange rate pass-through for the case of Canada, highlighting similarities and differences with respect to Sweden.[26]

	Exog ER	Can D	Can MP	Can S	Global D	Global S
NEER	23	18	17	14	20	8
Inflation	8	15	12	10	51	4

Table 3: Forecast error variance decomposition (FEVD) of the the CAD/USD exchange rate and CPI inflation for Canada. The numbers represent percentages of the forecast error variance due to each shock.

4.1 Decompositions

The exogenous exchange rate shock explains only 23 percent of the variations of the exchange rate at the 8-quarter horizon (Table 3), similarly to the case of Sweden. We confirm that our structural BVAR assigns a larger role to fundamental shocks in explaining exchange rate movements. Compared to the case of Sweden, global shocks have a somewhat larger role for the the CAD/USD exchange rate (28 percent) and the domestic demand shock is not the main driver of exchange rate fluctuations. Global shocks – in particular demand shocks – explain more than half of the variations in inflation. This is in line with findings in Justiniano and Preston (2010a), who use a larger empirical model for Canada and US and obtain a foreign variance share of 42 percent after 8 quarters for Canadian inflation during the period 1982-2007. Note that commodity price shocks may be included in our global demand shocks, as mentioned in section 2.3.

In Figure 4 we report the shock decomposition of the deviations across time of the CAD/USD exchange rate from its steady state. As anticipated by the analysis of the FEVD, we can notice that exogenous exchange rate shocks are important throughout the sample period, but fundamental shocks matter more. In particular, global shocks were the most important drivers of the exchange rate during the financial crisis. Negative global shocks gave rise to the currency depreciation during the crisis, while positive domestic shocks, mostly demand and exogenous exchange rate shocks, contributed to its strengthening after the crisis. This result is in line with the interpretation of an imported crisis and is in contrast to Forbes et al. (2017), who find a larger role of global shocks after rather than during the crisis. During the period 2013-2016, the CAD/USD exchange rate experienced a large depreciation, that is of a magnitude outmatched only by the depreciation during the financial crisis. This depreciation appears to be due primarily to negative domestic shocks,

[26] The impulse response functions for the Canadian model are reported in Figures B.1 - B.6 in Appendix B. Similarly to the model for Sweden, they are rescaled to generate a one percent depreciation of the CAD/USD exchange rate after 4 quarters.

especially exogenous exchange rate shocks, with a smaller role for negative global demand shocks.[27]

Figure 5 shows that, on average, inflation has been higher and closer to the target in Canada than in Sweden. Excluding the crisis, periods of low inflation are rare and less severe than in Sweden. Overall, the decomposition of inflation confirms the large role of global demand shocks. The low inflation during the financial crisis is primarily due to negative global demand shocks, while the recovery in the following periods is motivated by stronger demand both at home and abroad. The period 2012-2014 is characterized by relatively weak inflation developments, with a crucial role of domestic and global demand shocks. In the next section we explain how to reconcile this subdued inflation dynamics with the large depreciation of the CAD/USD exchange rate during the same period.

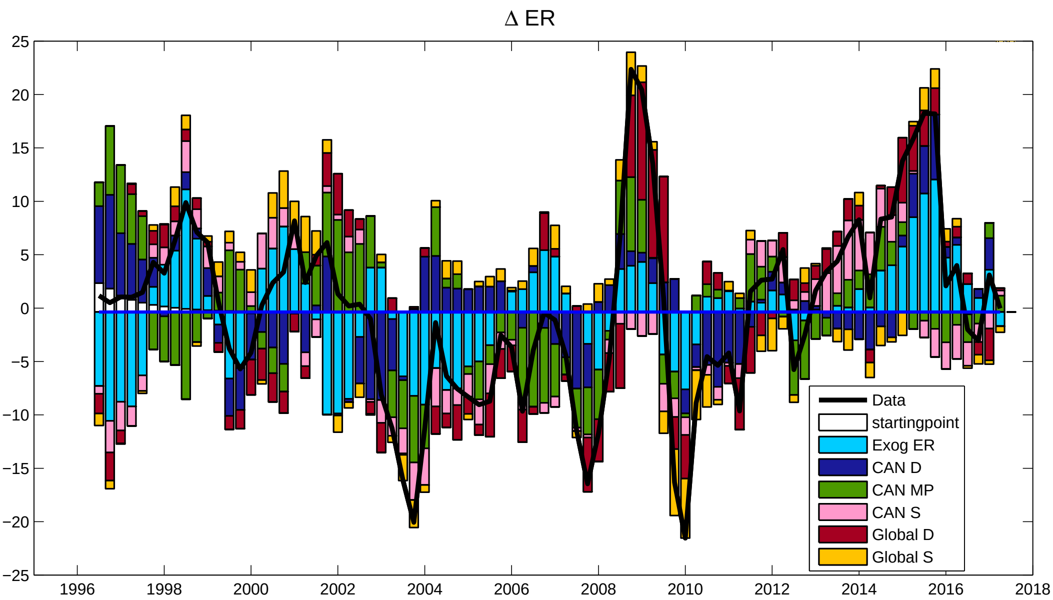

Figure 4: Historical decomposition of the the CAD/USD exchange rate, year-on-year changes.

4.2 Conditional exchange rate pass-through

Figure 6 reports the CERPT for Canada, confirming an important result obtained with Swedish data. Both the domestic and the global demand shocks feature a neg-

[27] We note again that there are a number of possible explanations behind exogenous exchange rate shocks, as discussed in section 2.3.

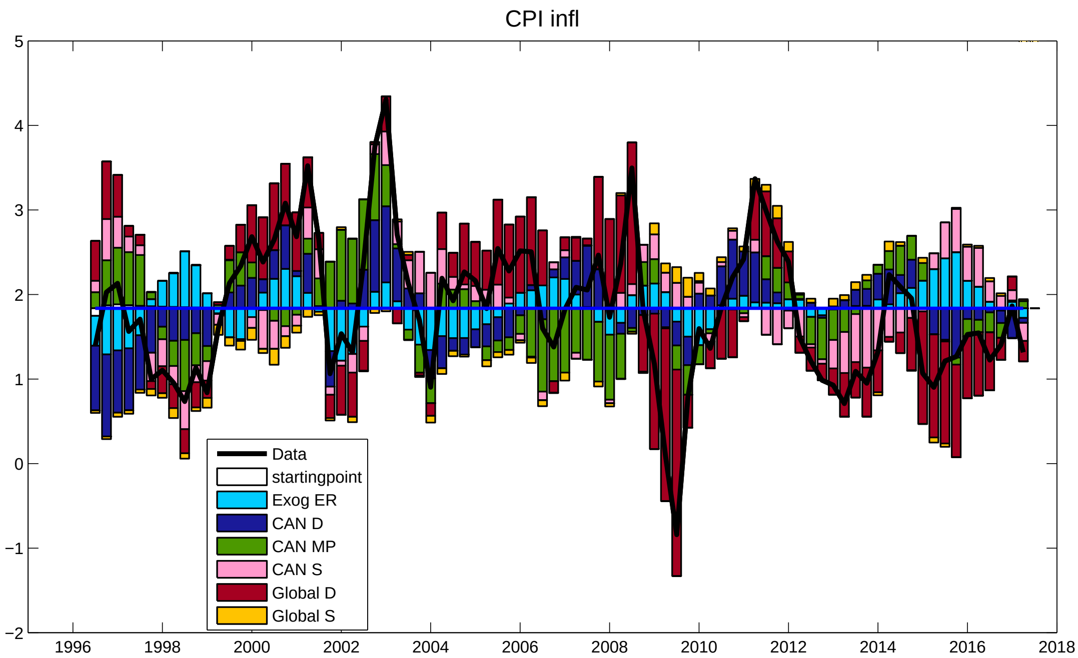

Figure 5: Historical decomposition of the the Canadian CPI inflation, year-on-year changes.

ative pass-through. After a depreciation of the currency due to negative domestic demand shocks, consumer prices in Canada decrease by 8 to 10 percent, in line with the results for Sweden. The deflationary effect is even larger than in the Swedish case after a global demand shock that depreciates the currency – around 20 percent on impact and 27 percent in the long run. Hence, we can conclude that the negative pass-through after the global demand shock is not a feature of Sweden, but may be a feature of small open economies. It is due to the currency depreciation that follows a negative global demand shock (Figure B.5 in Appendix B). When demand weakens at a global level, firms in Canada experience deflationary pressure. Even though the Canadian dollar depreciates, firms do not pass-through all of the increase in import costs to domestic consumers, dampening any increases in consumer prices. Moreover, the impulse response function of the relative GDP of Canada reveals that Canadian GDP drops more than US GDP after a negative global demand shock.[28]

It is interesting to notice that the monetary policy shock features the highest pass-through to consumer prices also for Canada, of around 10 percent. The exogenous exchange rate shock features a pass-through of 5 percent, in line with reduced-form

[28] This is not the case for Sweden. Instead, Swedish GDP responds more than the trade-weighted foreign GDP after a global supply shock.

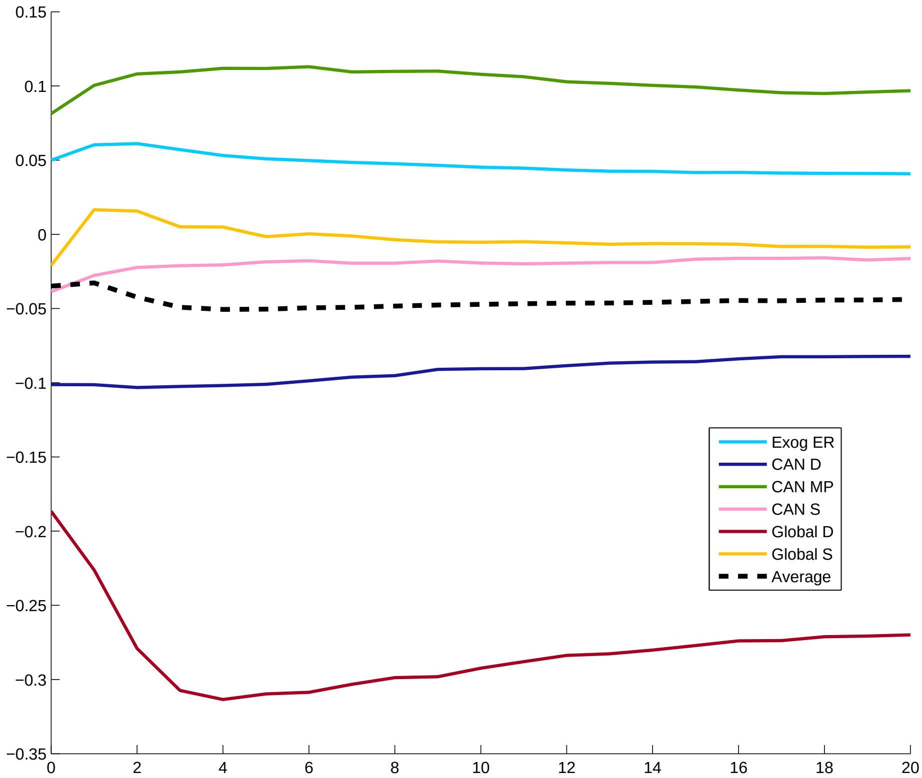

Figure 6: Exchange rate pass-through to CPI by shock and on average across 20 quarters, for the benchmark model in Canada

estimates in Gagnon and Ihrig (2004), while it is smaller than the reduced-form estimate in Forbes et al. (2017).

The pass-through after domestic and global supply shocks is small and slightly negative, but from the impulse response functions (Figure B.4 and B.6 in Appendix B) we notice that the probability bands for this estimate are large and around zero. We thus interpret these estimates with caution. Finally, the average pass-through turns out to be small and slightly negative. Given the way we have constructed the average pass-through, this result is due to the large negative pass-through after the global demand shock and its large role for the fluctuations of the exchange rate.

The conditional exchange rate pass-through helps us to rationalize the behaviour of exchange rate and inflation. The large depreciation of the CAD/USD exchange rate during the period 2013-16 coincided with subdued inflation because negative domestic and global demand shocks contributed to the depreciation of the currency, and these feature a negative pass-through. Moreover, the main driver of the depreciation, the exogenous exchange rate shock, has a very small, albeit positive, pass-through to inflation.

5 Robustness

In this section, we report robustness analysis with regards to selected data series and the methodology.[29]

5.1 Data sensitivity analysis

We have estimated the BVAR model for Sweden using the HP filter to detrend the repo rate, instead of the DSGE-based measure of the neutral rate. Results were largely unchanged.

In recent years, unconventional monetary policy measures have become more and more relevant in many economies, making the policy rate an insufficient indicator of the overall stance of monetary policy. This was also the case in Sweden, where a quantitative easing (QE) programme was started in 2015. 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 QE in 2015. The results we obtain are not much affected, which is likely due to the fact that the interest rate measure changes only in the last couple of years of our sample.

5.2 Methodology

We have tried alternative specifications of our model to verify the robustness of our results. First, we have increased the number of lags from 2 to 4, in order to have a full year in the lagged values. Our results remain intact.

Second, we have omitted the identifying restriction for the negative response of the exchange rate to the domestic demand shock. Having a negative sign implies a negative exchange rate pass-through on impact. Of course, the impact restriction does not imply a negative pass-though in the medium and long run, but we have tried

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

this specification for robustness nevertheless. Our results still hold: we still obtain a negative pass-through after domestic and global demand shocks, both for Sweden and for Canada.

Third, we have modified our identifying restrictions for global shocks, following the approach in Ha et al. (2019). We have used sign restrictions to impose that the global demand shock generates instantaneous comovement between output and inflation, while the global supply shock moves them in opposite way, omitting the zero long-run restriction for the global demand shock. Using this identification for both economies, we obtain global shocks that are less precisely estimated. Most importantly, both global demand and supply shocks have permanent effects on foreign and domestic GDP, hence making the distinction more difficult. Therefore, we consider our baseline identification better suited for the analysis.

Fourth, in Appendix C we consider a model for Sweden similar to Forbes et al. (2018), where foreign inflation is used as proxy for global export price inflation, foreign GDP is replaced by import prices and Swedish GDP is included in growth rate instead of relative GDP level. We use two identification strategies. The first one is the same as in Forbes et al. (2018), delivering a global persistent shocks and a global temporary shock. The second one makes a modification, in order to distinguish between global demand and global supply, using a sign restriction on Swedish GDP. In both cases and unlike our benchmark model, we allow the domestic supply shock to be permanent as the global supply shock. Our results regarding the pass-through to consumer prices are similar. The exogenous exchange rate shock is not the main source of exchange rate fluctuations and features a small pass-through to consumer prices. The average pass-through is around zero. The monetary policy shock is still the shock with the highest positive pass-through, while the domestic demand shock features a negative pass-through. Moreover, one of the global shocks also features a negative pass-through (global transitory or global demand shock, depending on the identification strategy). The pass-through to import prices is higher than the one to consumer prices and the highest pass-through is obtained after one of the global shocks (global persistent or global supply shock, depending on the identification strategy). The domestic shocks of these models are highly correlated (correlation around 0.7) with the domestic shocks of the benchmark model, except for the supply shock that is allowed to be permanent in this case. We note, though, that using the same identification strategy as in Forbes et al. (2018) delivers responses to global shocks that are very imprecisely estimated, apart from the fact that we are not able to distinguish global demand from global supply, but only global temporary from global persistent shocks. In particular, the probability bands of the responses of the exchange rate contain the zero, hence there is large uncertainty around the pass-through following these shocks. This is one more reason to prefer the model specification where global demand and global supply shocks are distinguished.

6 Discussion and cross-country comparison

We can draw some general conclusions from the analysis of the conditional exchange rate pass-through in Sweden and Canada. Fundamental shocks, other than the exogenous exchange rate shock, explain about three quarters of exchange rate fluctuations. Hence, our model shows more "exchange rate connect" than the literature on exchange rate forecasting and its determinants (see Obstfeld and Rogoff (2000)).[30] Domestic and global demand shocks feature a negative pass-through. In absolute terms, the pass-through after global demand shocks is the highest. These are also the main driver of domestic inflation, although not of exchange rate fluctuations. Monetary policy shocks feature the highest (positive) pass-through, as found earlier in the literature.

In order to verify the nature of our global demand shocks, we have computed the correlation of shocks across the models for Sweden and Canada. We find a high correlation for the global demand shocks across the two models, equal to 0.8, despite the different sets of data used. This high correlation confirms that it is indeed a global shock. The global supply shocks feature a lower, but still positive, correlation (0.4). Domestic shocks are weakly correlated across the two economies, as they reasonably should be. The lowest correlation, equal to 0.08, characterizes domestic monetary policy shocks.

7 Conclusions

In this paper, we use structural Bayesian VAR models to study the drivers of the fluctuations of the exchange rate and consumer prices in two small open economies, Sweden and Canada. In our analysis, we identify four domestic shocks (supply, demand, monetary policy and exogenous exchange rate shocks) and two global shocks (supply and demand shocks) through zero short-run and long-run restrictions as well as sign restrictions. Our methodological contribution to the literature is in the tractable identification of global demand and global supply shocks. These shocks are

[30] Recent research makes a case for an "exchange rate reconnect", especially after the financial crisis (Engel and Wu (2018), Lilley et al. (2019)).

especially important for small open economies with extensive trade with the rest of the world, like Sweden and Canada. As a confirmation of the success of our identification, we find the global shocks to be positively correlated across the two country-specific models, especially the demand shocks.

Looking at the comovement between exchange rate and consumer prices, we find a large variation depending on the shock driving exchange rate fluctuations. The highest pass-through from exchange rate to prices is obtained following global supply or monetary policy shocks. The risk-premium shock always features a small pass-through and explains at most about a fifth of the exchange rate fluctuations. This is an important finding that highlights the limitations of using models where the exchange rate is predominantly explained by its own exogenous shocks to assess the effects of exchange rate movements on prices. Domestic and global demand shocks generate a pass-through to consumer prices of a negative sign. 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. Other VAR studies using different identification strategies generally find the pass-through following the domestic demand shock to be negative. That the pass-through is negative following also the global demand shock is novel to our study and seems related to the improved identification of global shocks. The global demand shock also turns out to be the main driver of domestic inflation.

In terms of policy implications, our work stresses the importance of not relying on rules of thumb or single-equation models to assess the implications of exchange rate movements on prices. We show that a negative global outlook due to demand-like shocks is likely to weaken the currency of a small open economy, while at the same time exerting downward pressure on domestic consumer prices. This scenario may be especially important for the economy, if it takes place at a time when inflation has been low for long and policy rates are close to their effective lower bound.

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A Appendix: Impulse responses for Sweden

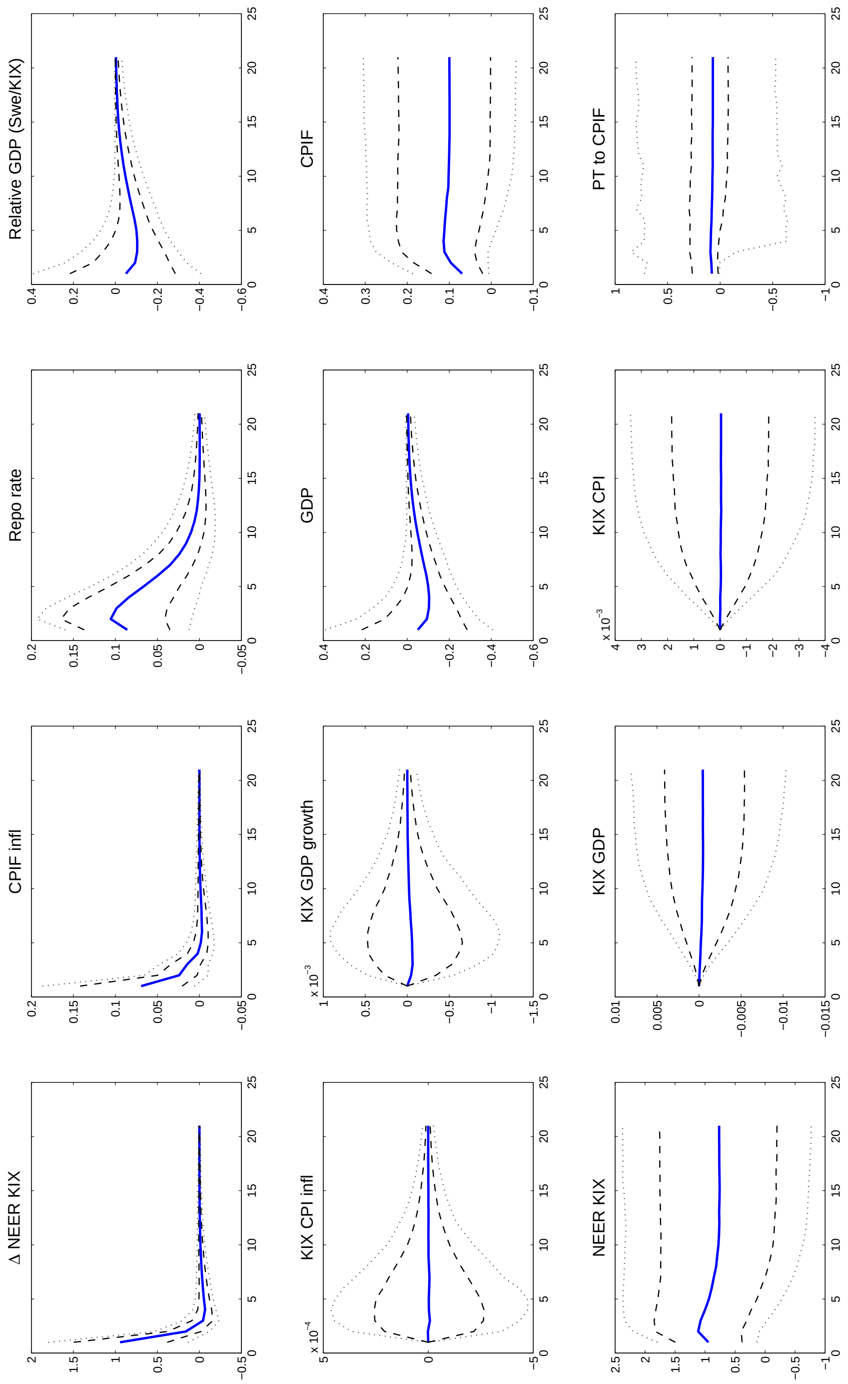

Figure A.1: Impulse responses to an exogenous KIX exchange rate shock in the benchmark model. The graphs report the median impulse response (solid line) with the 68 percent interval (dashed lines) and the 90 percent interval (dotted lines). The responses are rescaled to cause a depreciation of the Swedish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

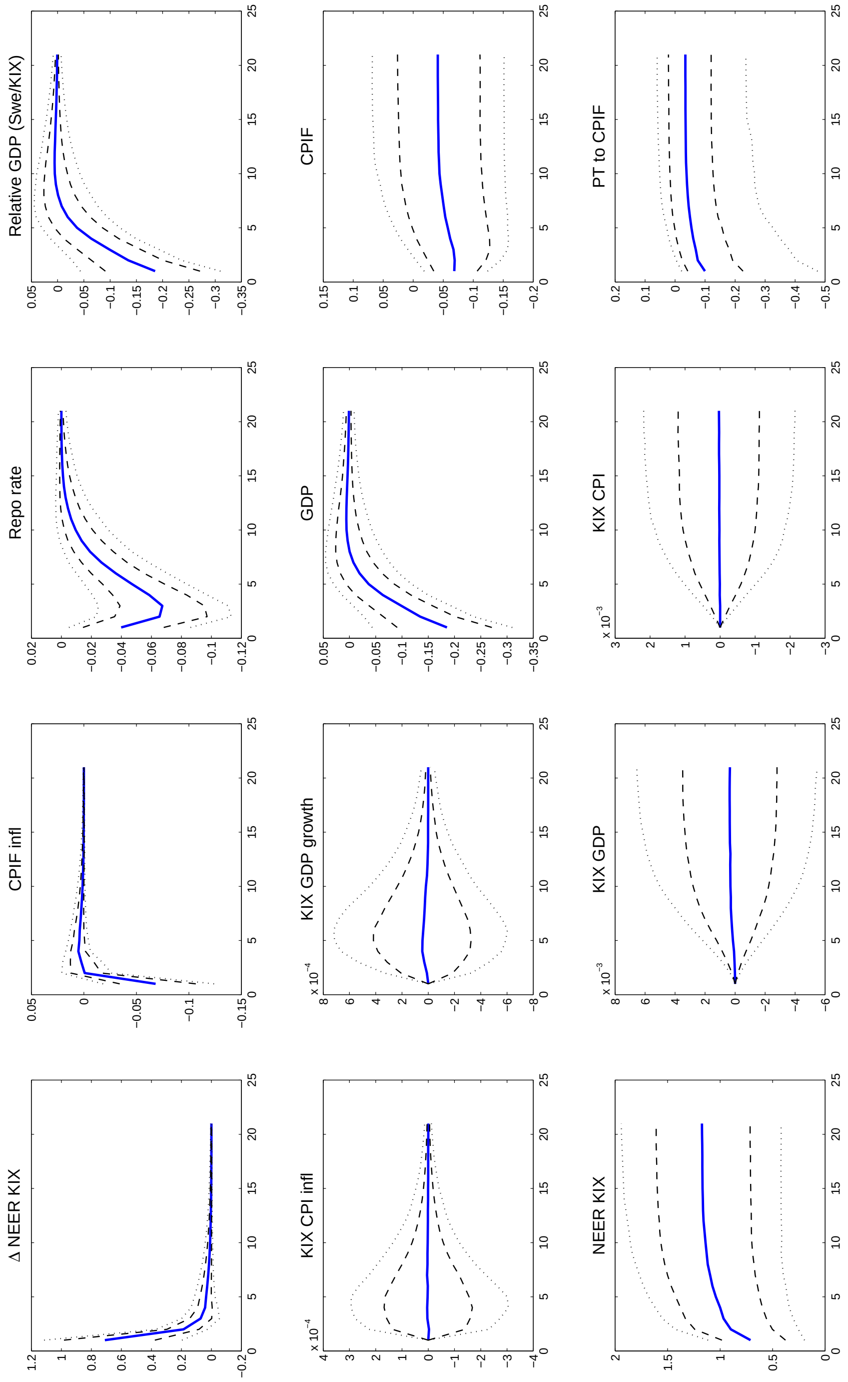

Figure A.2: Impulse responses to a Swedish demand shock in the benchmark model. The graphs report the median impulse response (solid line) with the 68 percent interval (dashed lines) and the 90 percent interval (dotted lines). The responses are rescaled to cause a depreciation of the Swedish Krona by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

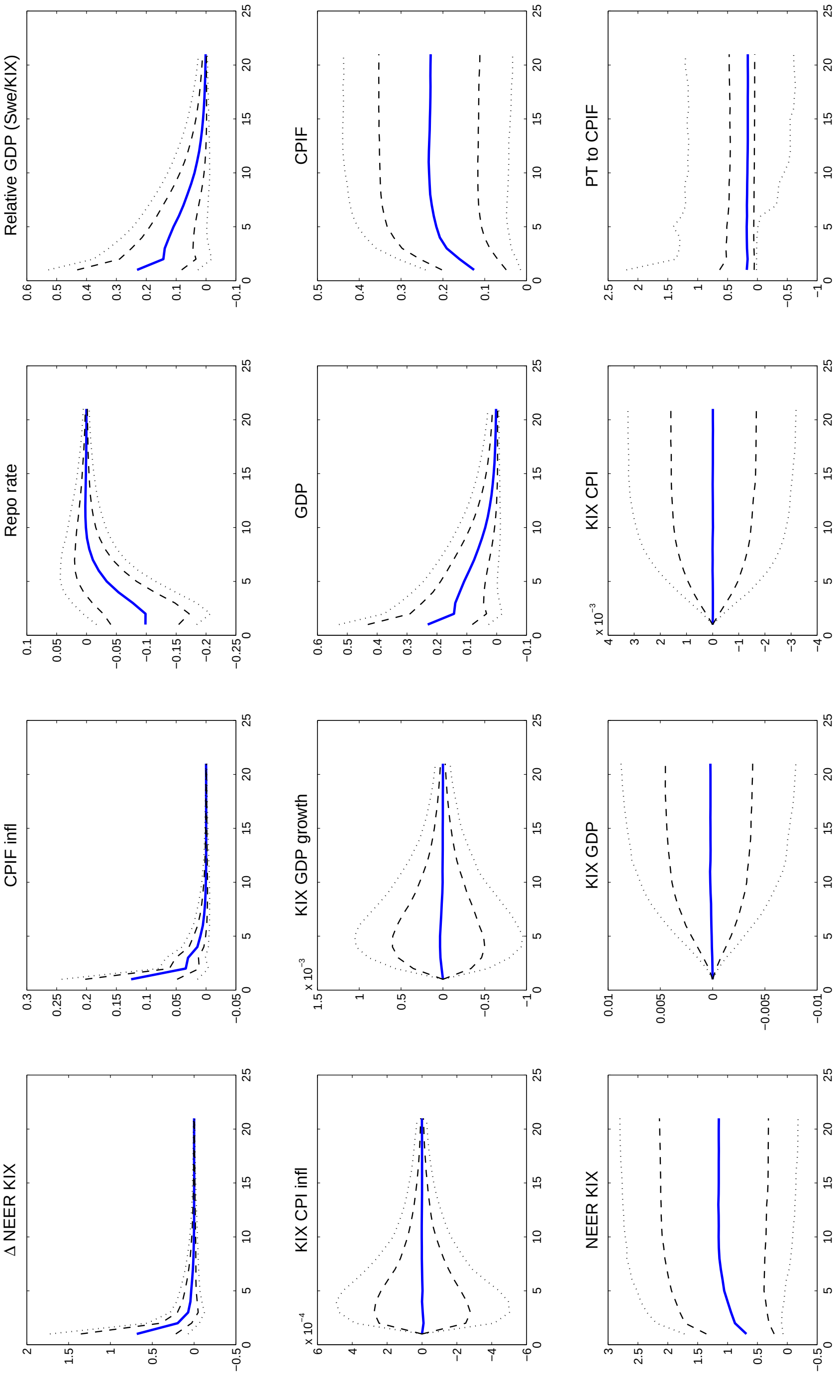

Figure A.3: Impulse responses to a Swedish monetary policy shock in the benchmark model. The graphs report the median impulse response (solid line) with the 68 percent interval (dashed lines) and the 90 percent interval (dotted lines). The responses are rescaled to cause a depreciation of the Swedish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

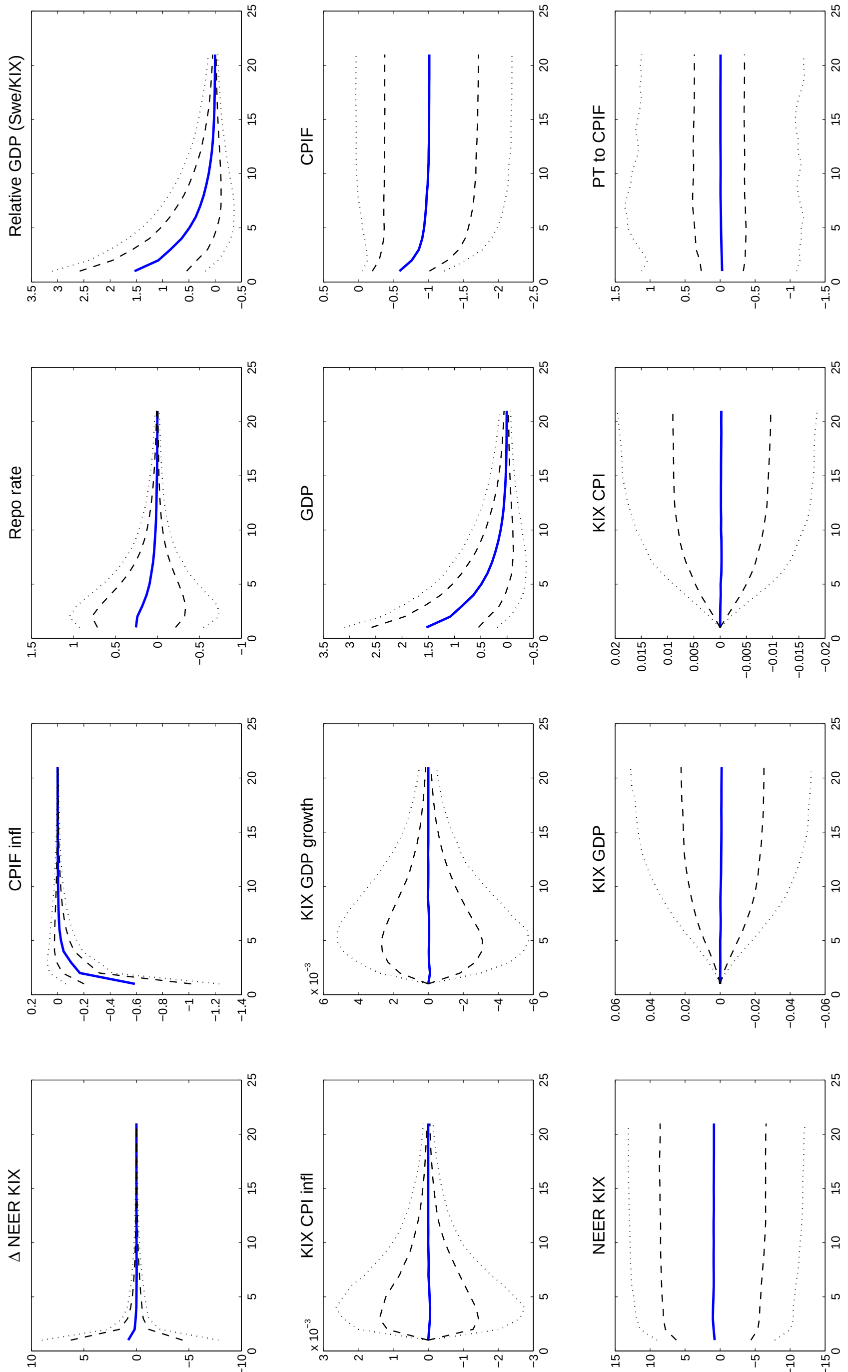

Figure A.4: Impulse responses to a Swedish supply shock in the benchmark model. The graphs report the median impulse response (solid line) with the 68 percent interval (dashed lines) and the 90 percent interval (dotted lines). The responses are rescaled to cause a depreciation of the Swedish Krona by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

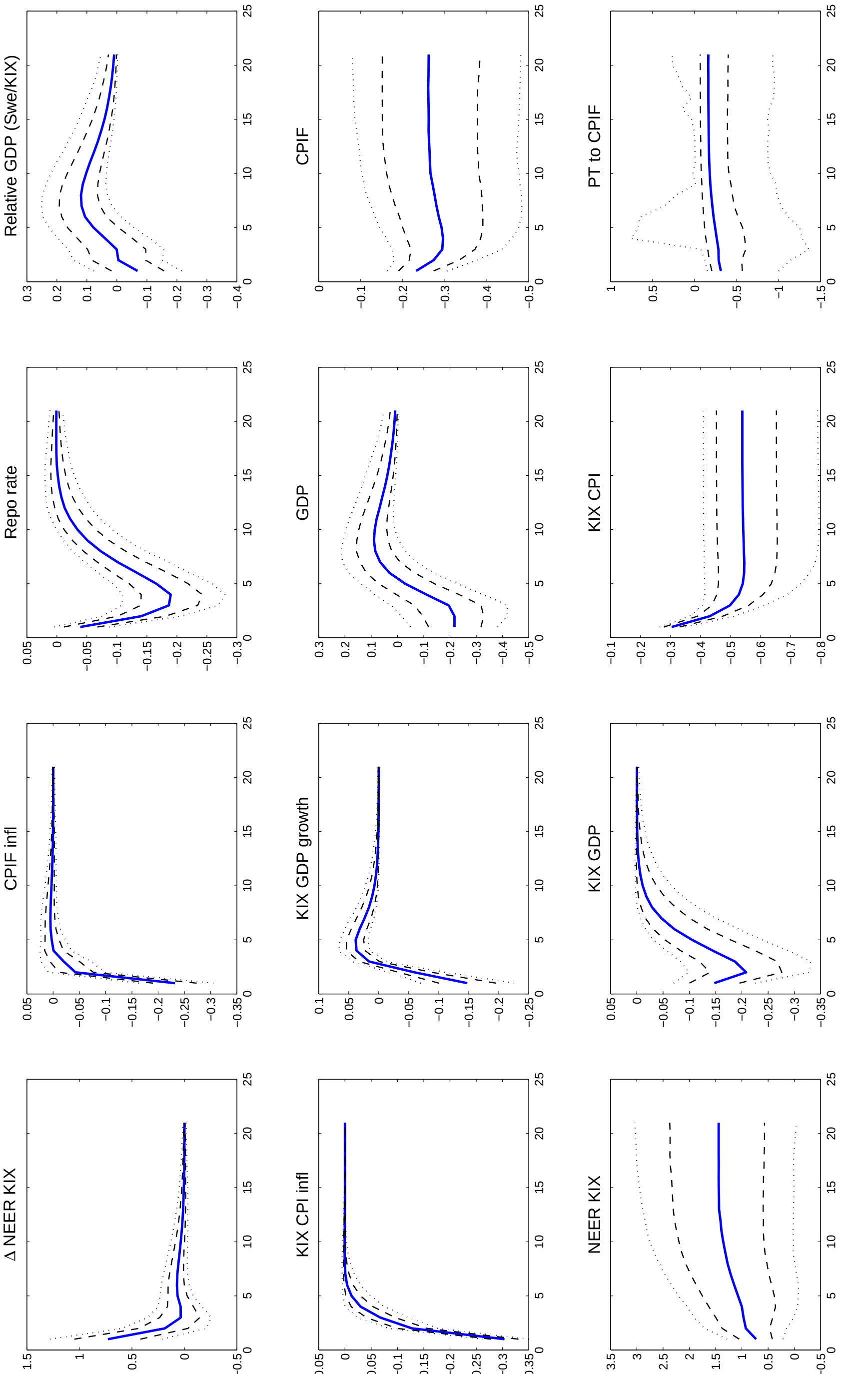

Figure A.5: Impulse responses to a global demand shock in the benchmark model. The graphs report the median impulse response (solid line) with the 68 percent interval (dashed lines) and the 90 percent interval (dotted lines). The responses are rescaled to cause a depreciation of the Swedish Krona by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

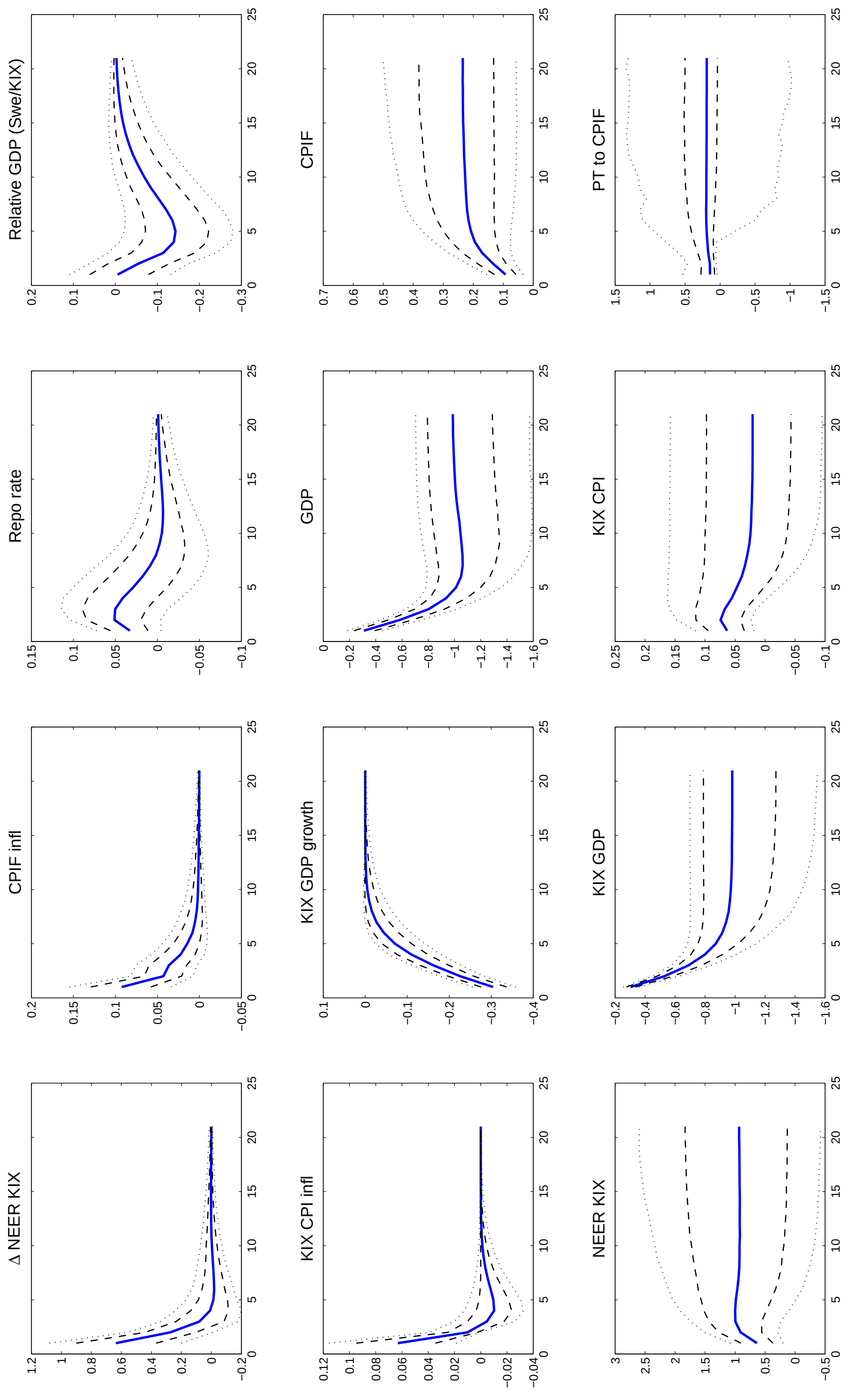

Figure A.6: Impulse responses to a global supply shock shock in the benchmark model. The graphs report the median impulse response (solid line) with the 68 percent interval (dashed lines) and the 90 percent interval (dotted lines). The responses are rescaled to cause a depreciation of the Swedish Krona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

B Appendix: Impulse responses for Canada

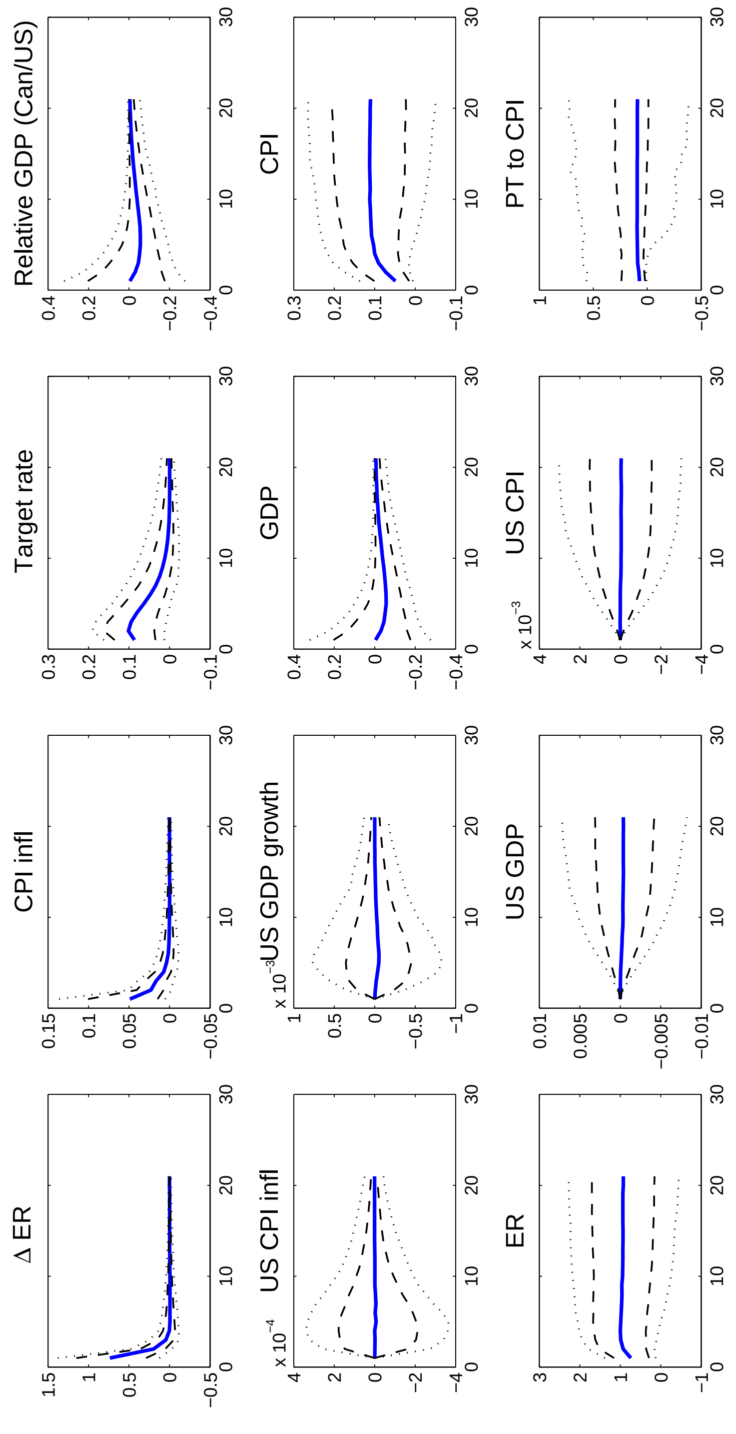

Figure B.1: Impulse responses to an exogenous CAD/USD exchange rate shock in the benchmark model. The graphs report the median impulse response (solid line) with the 68 percent interval (dashed lines) and the 90 percent interval (dotted lines). The responses are rescaled to cause a depreciation of the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

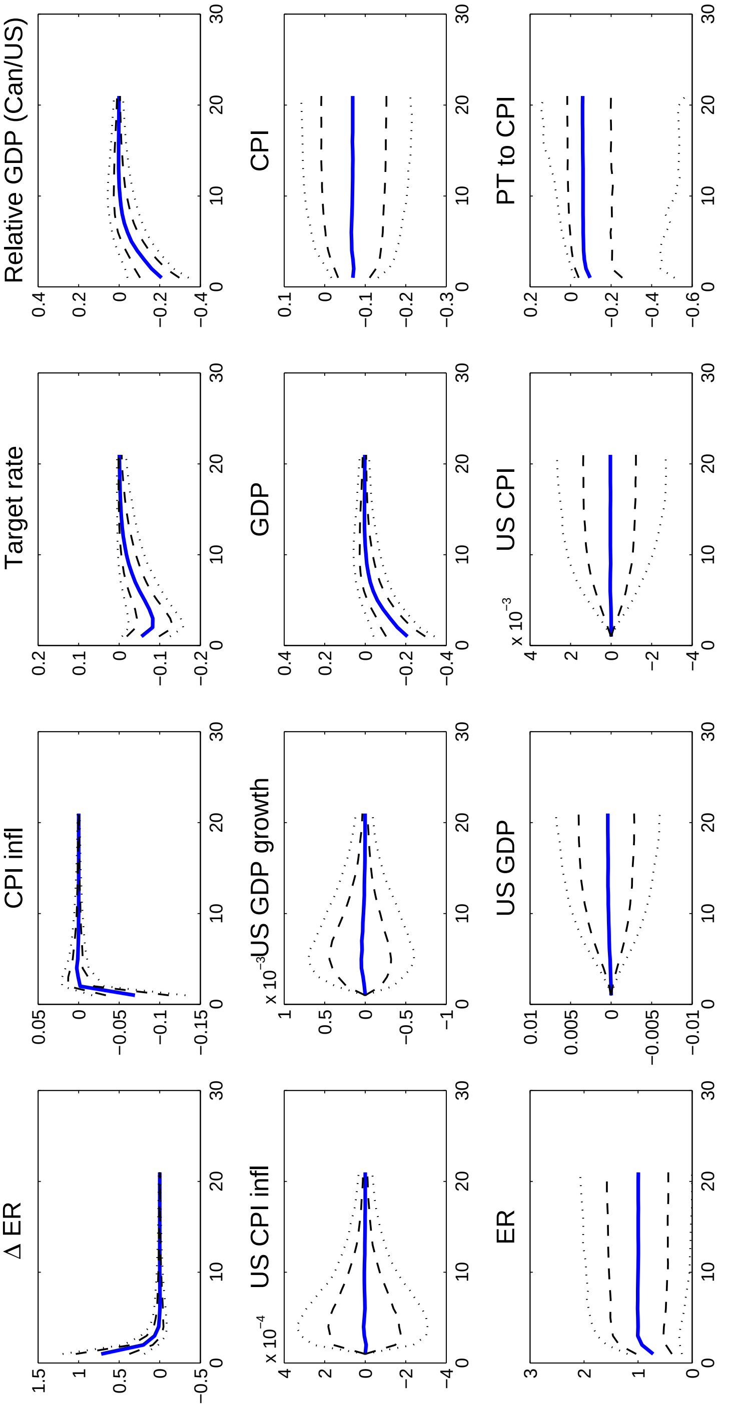

Figure B.2: Impulse responses to a Canadian demand shock in the benchmark model. The graphs report the median impulse response (solid line) with the 68 percent interval (dashed lines) and the 90 percent interval (dotted lines). The responses are rescaled to cause a depreciation of the CAD/USD exchange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

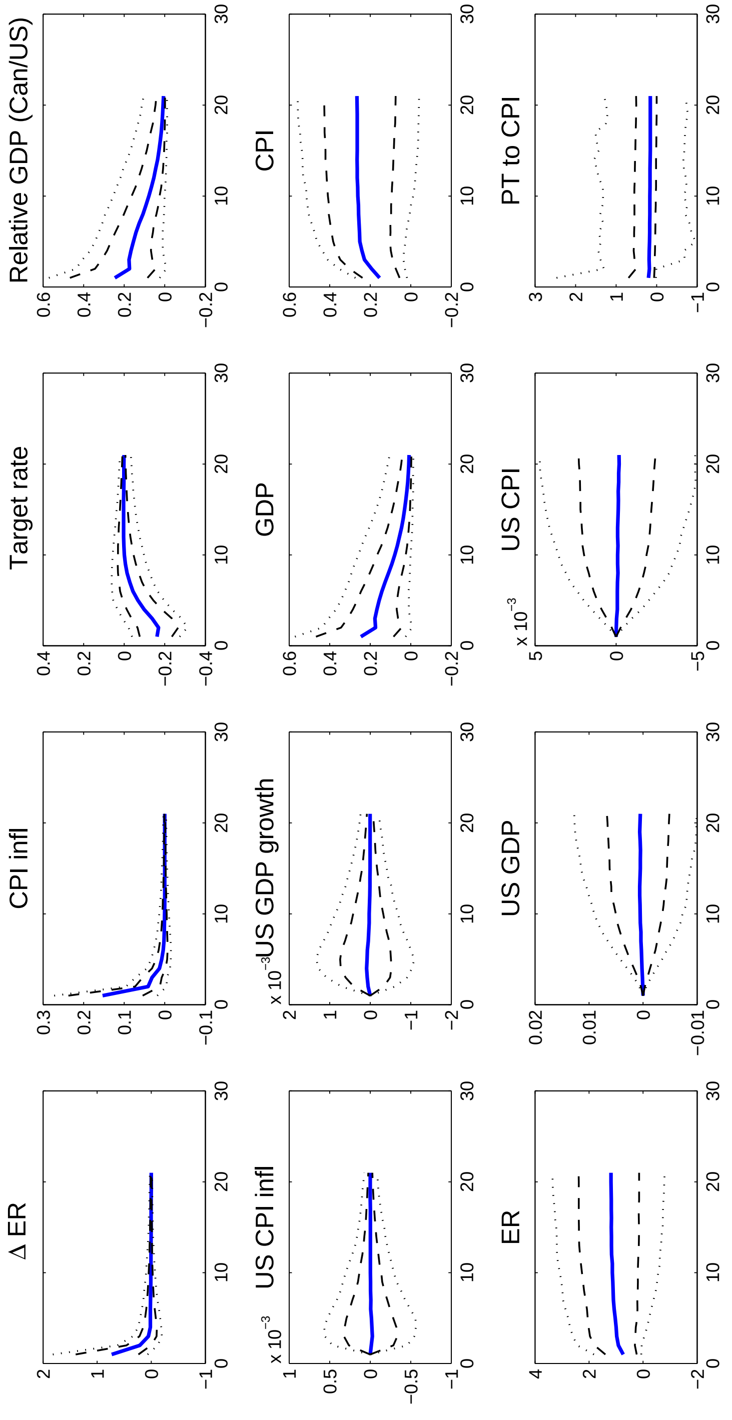

Figure B.3: Impulse responses to a Canadian monetary policy shock in the benchmark model. The graphs report the median impulse response (solid line) with the 68 percent interval (dashed lines) and the 90 percent interval (dotted lines). The responses are rescaled to cause a depreciation of the CAD/USD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

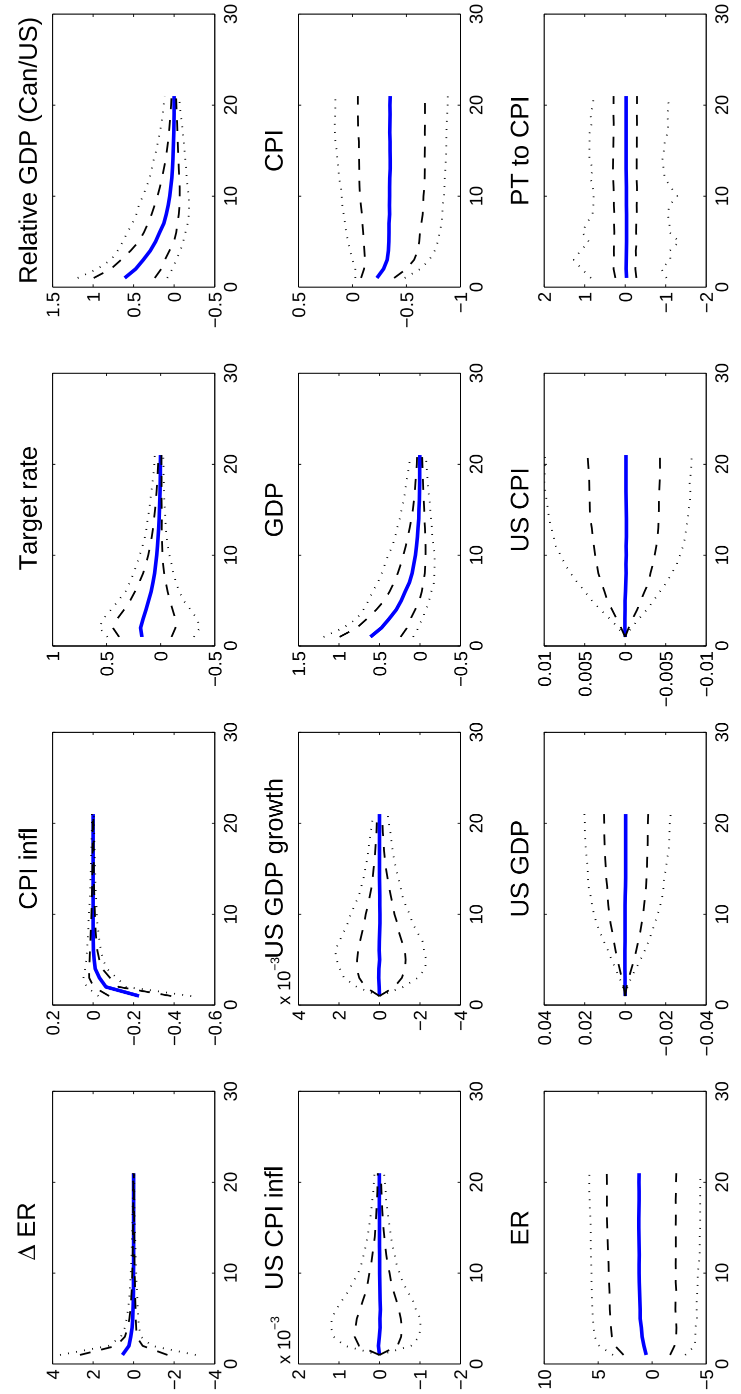

Figure B.4: Impulse responses to a Canadian supply shock in the benchmark model. The graphs report the median impulse response (solid line) with the 68 percent interval (dashed lines) and the 90 percent interval (dotted lines). The responses are rescaled to cause a depreciation of the CAD/USD exchange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

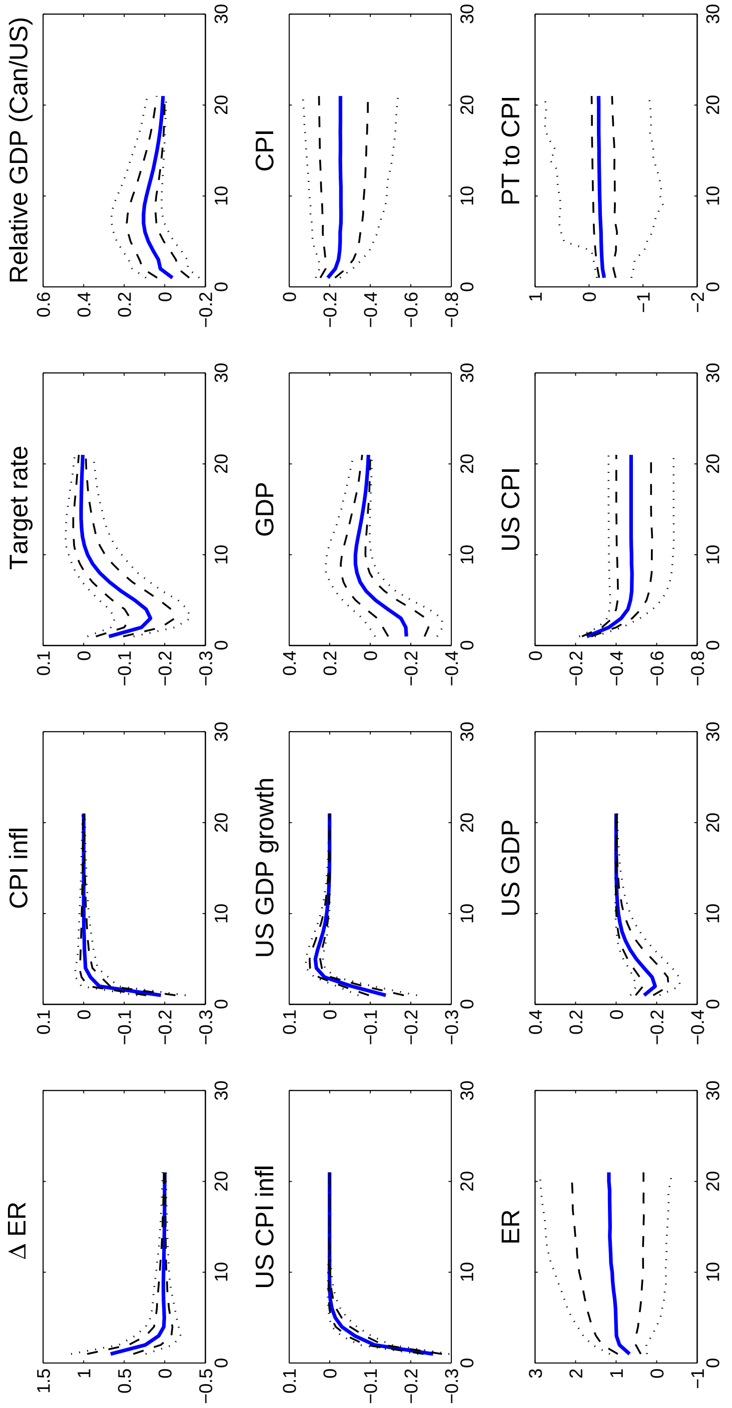

Figure B.5: Impulse responses to a global demand shock in the benchmark model. The graphs report the median impulse response (solid line) with the 68 percent interval (dashed lines) and the 90 percent interval (dotted lines). The responses are rescaled to cause a depreciation of the CAD/USD exchange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

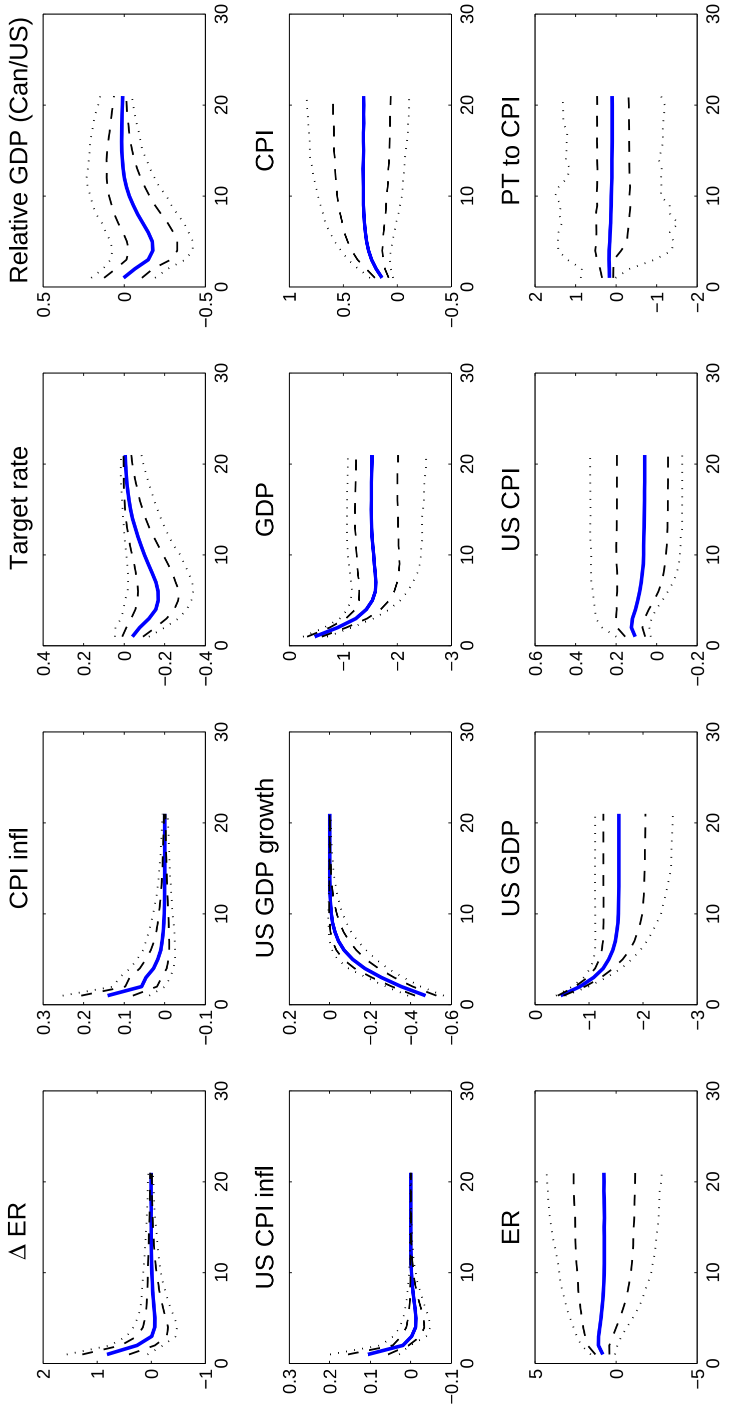

Figure B.6: Impulse responses to a global supply shock shock in the benchmark model. The graphs report the median impulse response (solid line) with the 68 percent interval (dashed lines) and the 90 percent interval (dotted lines). The responses are rescaled to cause a depreciation of the CAD/USD exchange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

C Appendix: Alternative BVAR with import prices, Sweden

In this section we present an alternative BVAR model for Sweden, that uses partly different data and identification strategy and is similar to the one initially proposed in Forbes et al. (2018). In our benchmark model, we studied the CERPT to *consumer* prices following each of the six identified shocks. In this alternative specification, we now also include *import* prices, measured through the import price index for total imports of goods and services produced by Statistics Sweden (IMPI), but exclude foreign quantities. We will also obtain a complementary set of results for consumer prices. We have to note that there may be problems related to the measurement of Swedish import prices, due to the way they are reported.[31] For these reasons, we have tried to use different import price measures.[32] We also consider two identification strategies. The first one is more similar to the one in our benchmark model, while the second one is identical to the one used in Forbes et al. (2018).

C.1 Identification

The restrictions we impose are summarized in Table C.1, and are similar to those used by Forbes et al. (2018), based on a standard open-economy DSGE model (see Benigno (2009) and Corsetti et al. (2010)).[33] The sign restrictions are again imposed on impact.

We rely on the assumption that Sweden is a small open economy, and thus that Swedish domestic shocks 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. Unlike the previous model, we do not use the assumption of exogeneity because only one of the variables used to identify the global shocks, namely import prices and export prices, is exogenous to the Swedish economy. Import prices can be affected by local shocks. This implies that we need to use a larger number of zero long-run restrictions. Moreover, we assume that only supply shocks are allowed to affect the

[31] 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.

[32] 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.

[33] 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, exports and third-country effects. These weights are the same ones used to calculate the effective exchange rate of the Swedish Krona.

	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						

Table C.1: Identifying restrictions for the alternative model. The signs on the diagonal are included in the table for clarity, and are only there for normalization purposes. The sign restrictions are imposed for 1 quarter following the shocks.

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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 increase 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. The domestic supply shock is assumed to move GDP and Swedish consumer price inflation in opposite directions.

The only changes to the identification strategy relate to domestic shocks. First, 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.[34] Second, unlike the previous model, the local supply shock is allowed to

[34]Our estimations have shown that Swedish import prices do not always tend to move in the expected direction. 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

be permanent. As we do not observe foreign GDP, it is difficult to separate between global permanent technology shocks and country-specific temporary ones. We therefore allow the domestic technology shock to have a permanent impact on Swedish GDP.

Regarding the global shocks, their identification is more difficult than before because we only have foreign prices in the model but not foreign quantities (which we included in our preferred specification above). Forbes et al. (2018) identify persistent and temporary global shocks by using a zero long-run restriction. The global persistent shock is allowed to affect the domestic GDP level in the long run, while the global temporary shock cannot. Here, we try to distinguish between demand and supply shocks, by using sign restrictions with respect to the Swedish GDP. We do this to ensure that the only shocks allowed to have a permanent impact on GDP have the character of technology shocks, rather than persistent demand shocks. Given the high positive correlation between the Swedish GDP and the foreign one, we identify the global supply shock as the permanent shock that generates negative comovement between import prices and Swedish GDP. The remaining global shock is then a demand shock.[35]

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shocks therefore may not be related to measurement issues only in Swedish data.

[35]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.

C.2 Results

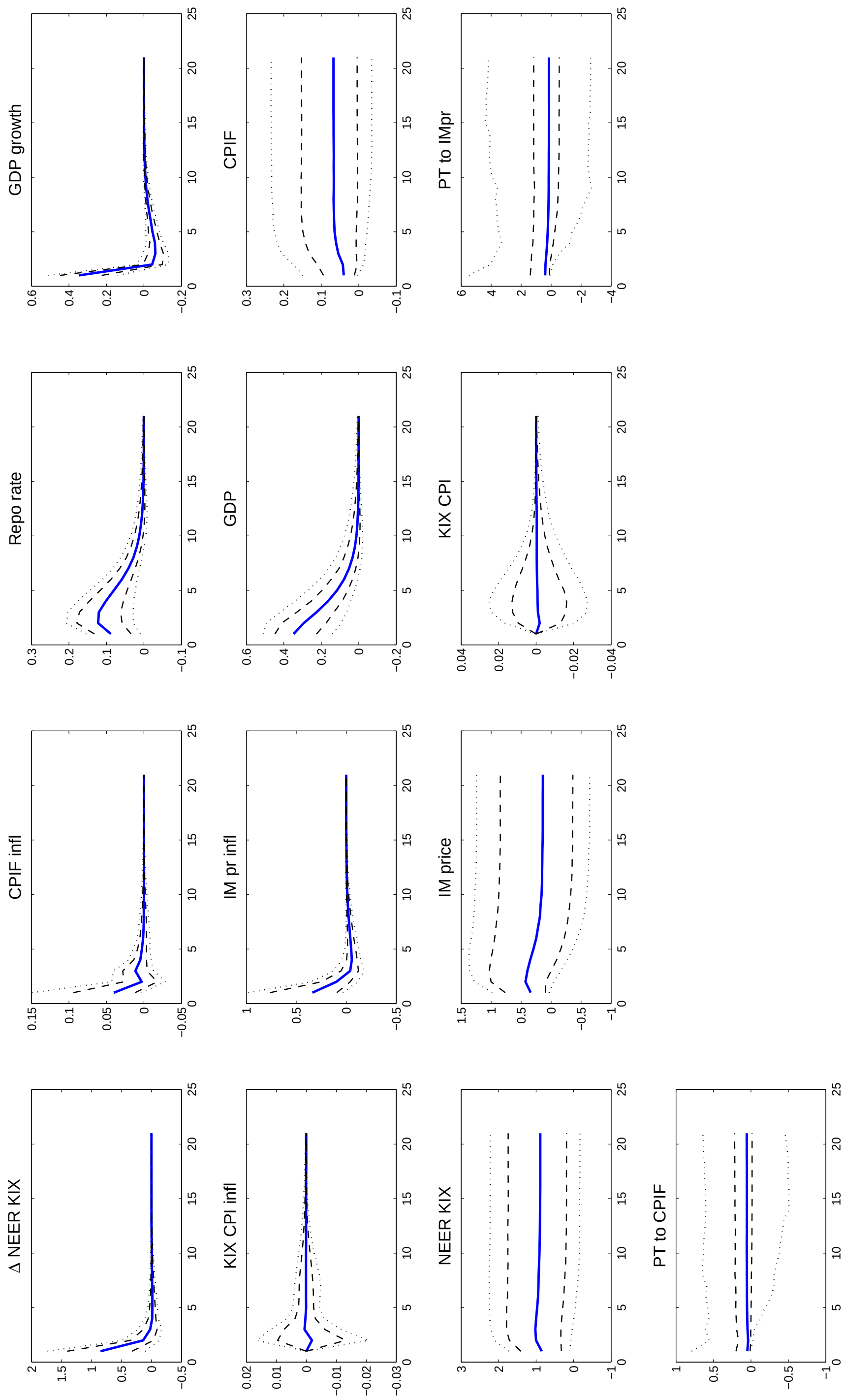

Figure C.1: Impulse responses to an exogenous exchange rate shock based on the alternative identification. The graphs report the median impulse response (solid line) with the 68 percent interval (dashed lines) and the 90 percent interval (dotted lines). The responses are rescaled to cause a depreciation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

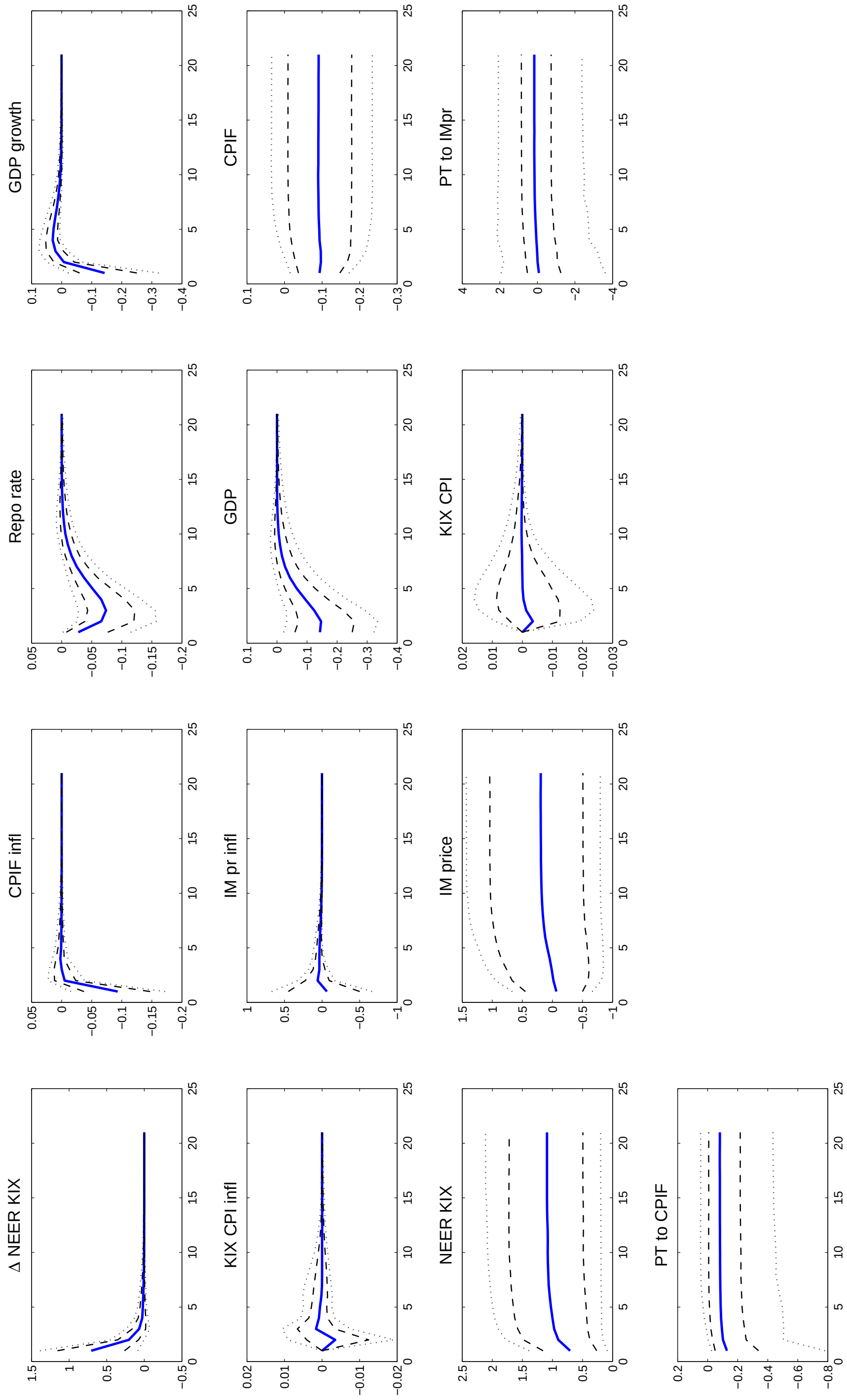

Figure C.2: Impulse responses to a Swedish demand shock based on the alternative identification. The graphs report the median impulse response (solid line) with the 68 percent interval (dashed lines) and the 90 percent interval (dotted lines). The responses are rescaled to cause a depreciation of the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

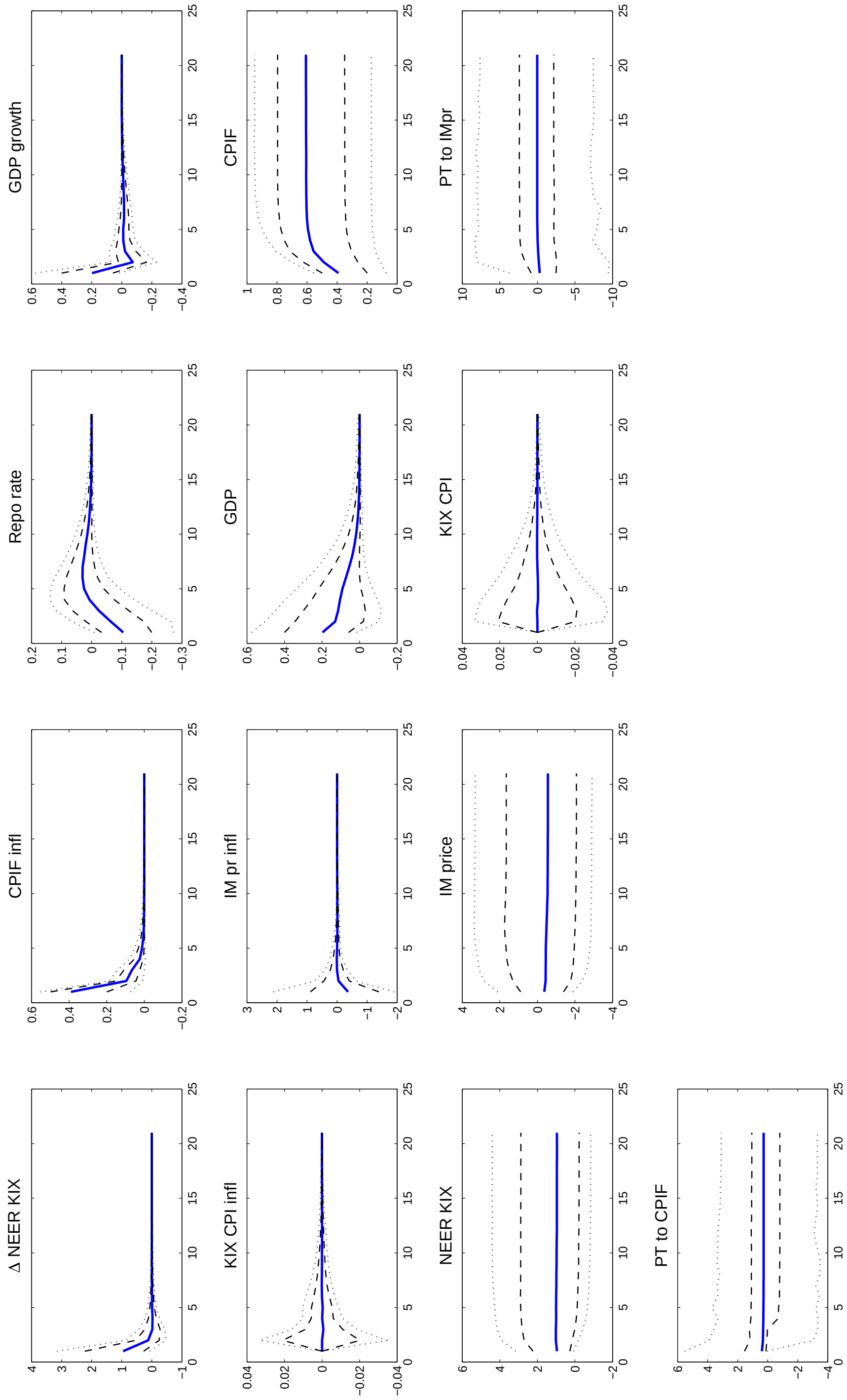

Figure C.3: Impulse responses to a Swedish monetary policy shock based on the alternative identification. The graphs report the median impulse response (solid line) with the 68 percent interval (dashed lines) and the 90 percent interval (dotted lines). The responses are rescaled to cause a depreciation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

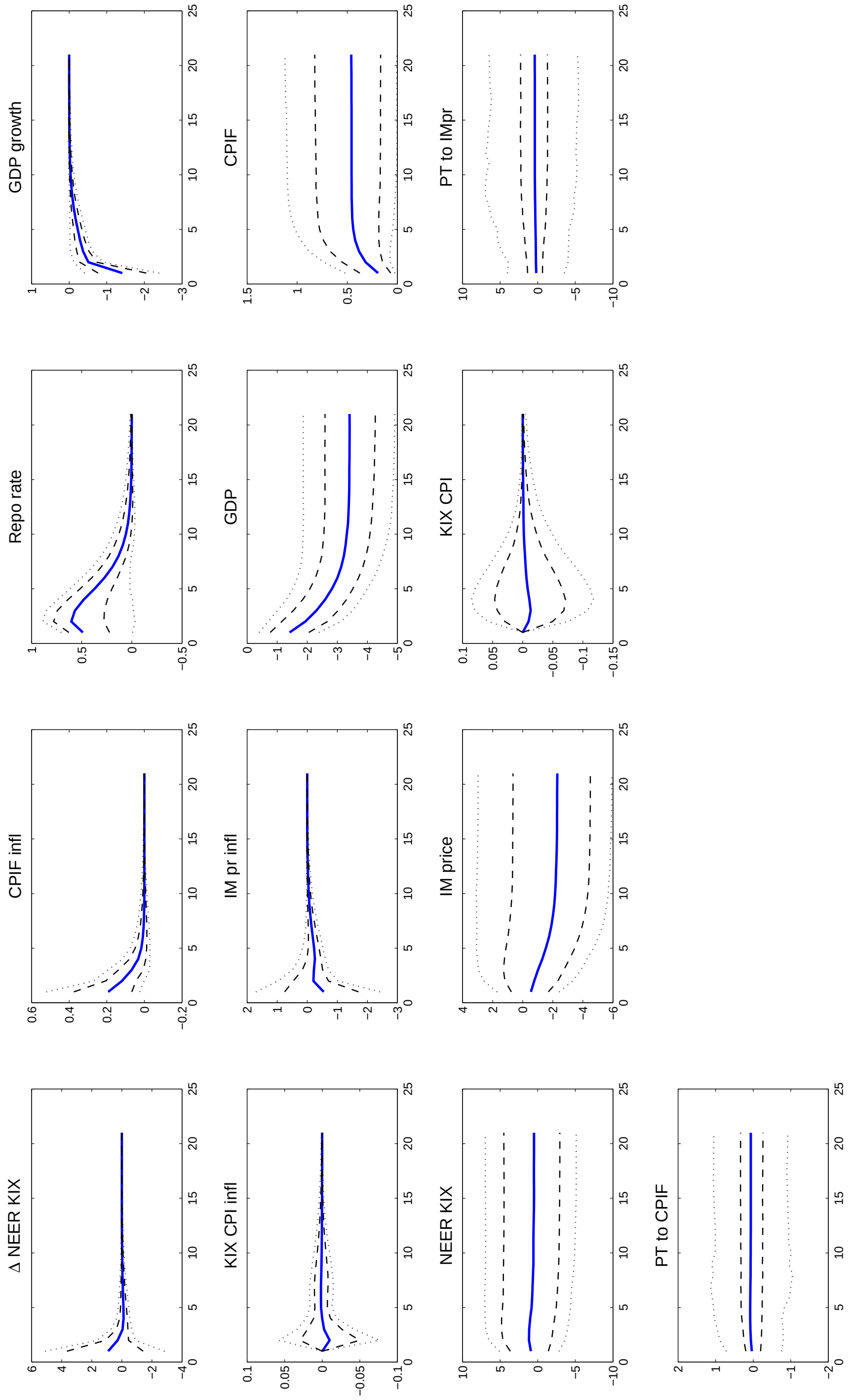

Figure C.4: Impulse responses to a Swedish supply shock based on the alternative identification. The graphs report the median impulse response (solid line) with the 68 percent interval (dashed lines) and the 90 percent interval (dotted lines). The responses are rescaled to cause a depreciation of the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

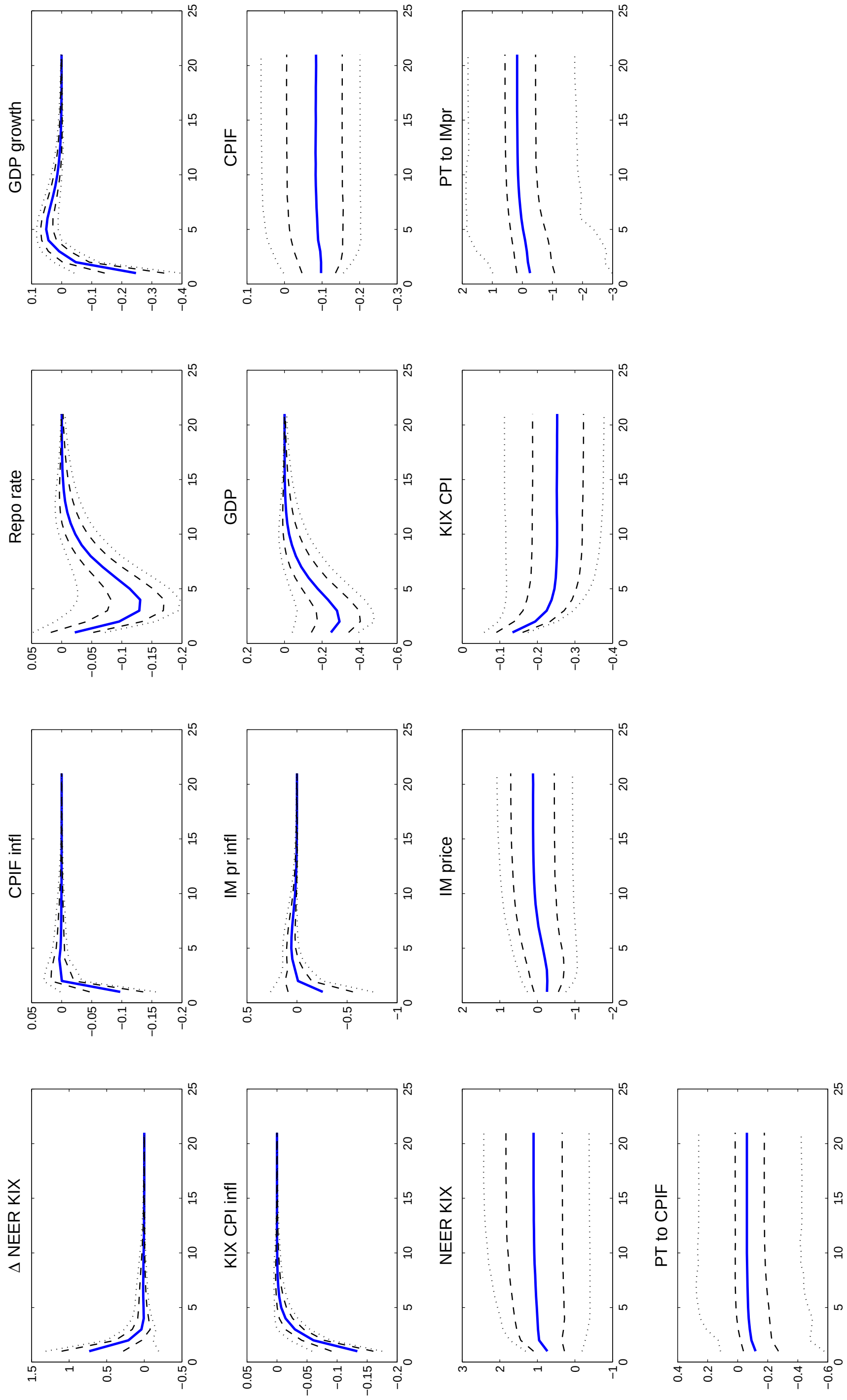

Figure C.5: Impulse responses to a global demand shock based on the alternative identification. The graphs report the median impulse response (solid line) with the 68 percent interval (dashed lines) and the 90 percent interval (dotted lines). The responses are rescaled to cause a depreciation of the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

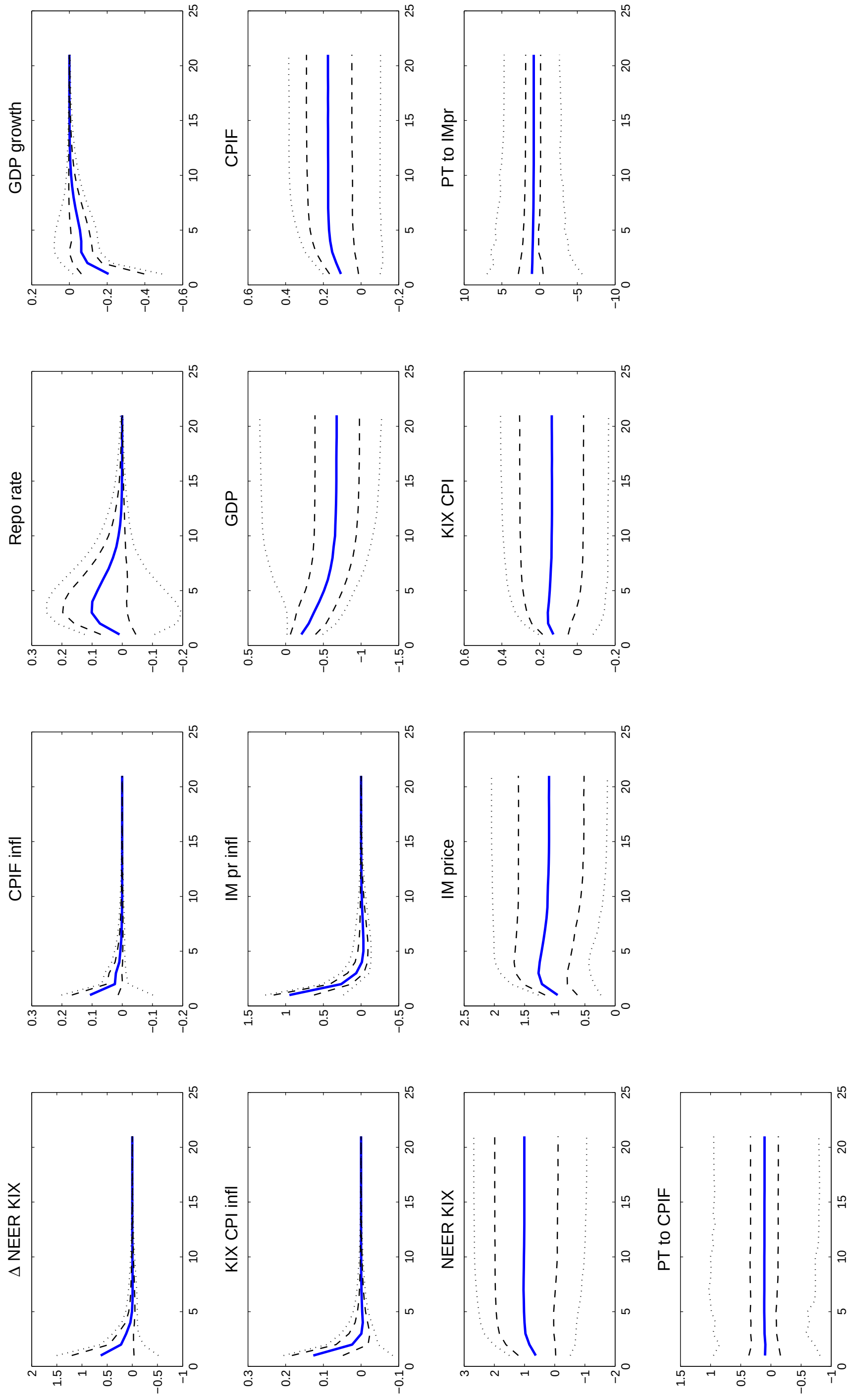

Figure C.6: Impulse responses to a global supply shock based on the alternative identification. The graphs report the median impulse response (solid line) with the 68 percent interval (dashed lines) and the 90 percent interval (dotted lines). The responses are rescaled to cause a depreciation of the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

The impulse responses of this model are reported in Figures C.1 - C.6. For import prices, the impulse responses show large probability bands. 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.

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

Table C.2: Forecast error variance decomposition (FEVD) of the the Swedish krona nominal effective exchange rate for the alternative model. The numbers represent percentages of the forecast error variance due to each shock.

Table C.2 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.

Figure C.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. This is in line with the findings in Forbes et al. (2018), where the global persistent shock features the largest pass-through to import prices in the UK. 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 – 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 inputs, suggests that the decreased global demand pressures 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. Note 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. After one year the pass-through after global demand shocks turn positive but it is always very low. 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 and large.

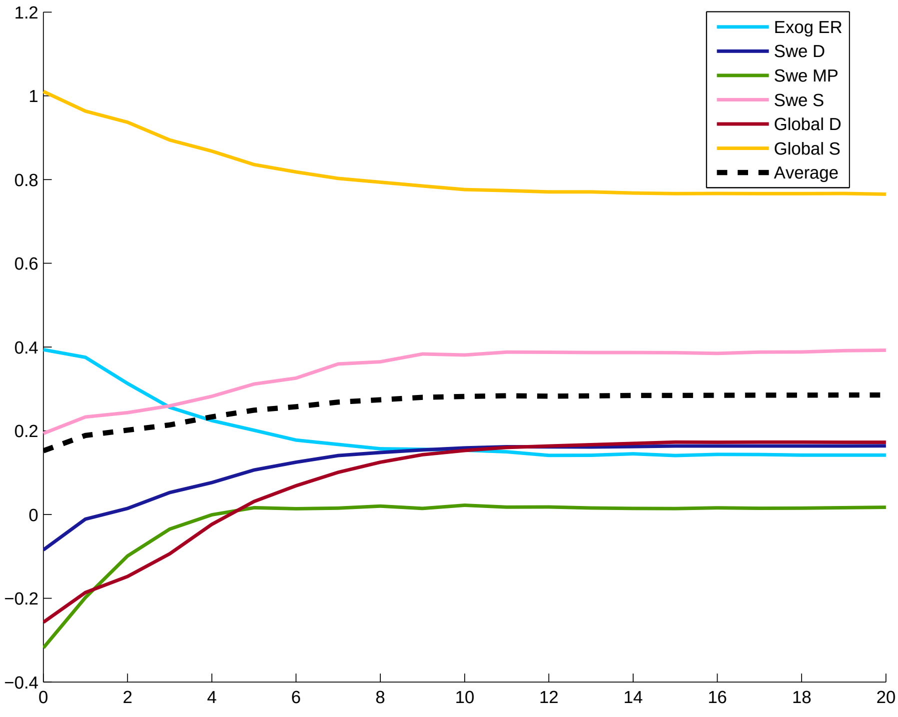

Figure C.7: Exchange rate pass-through to import price deflator by shock and on average across 20 quarters, for the alternative model in Sweden

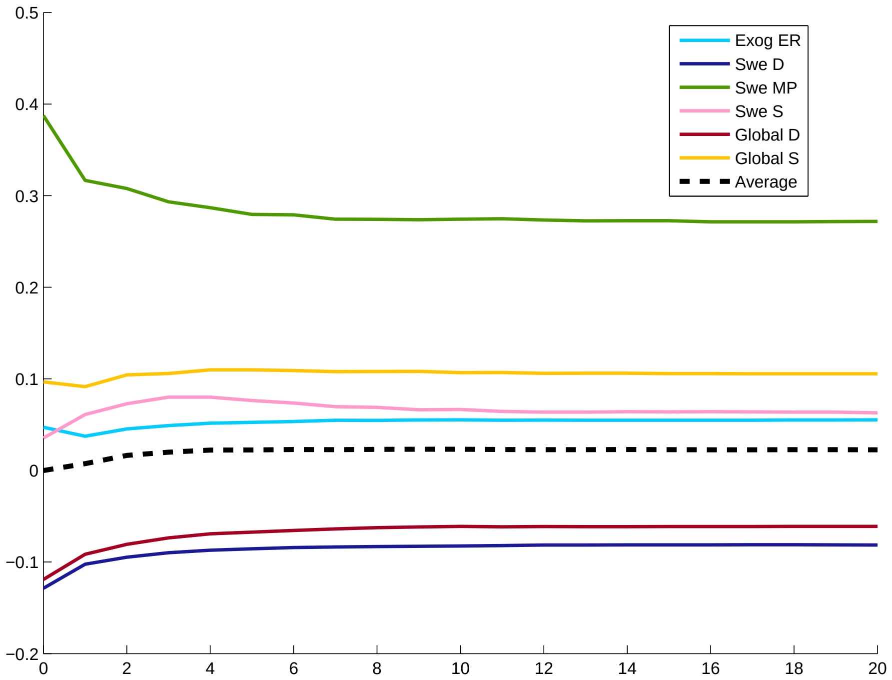

Figure C.8: Exchange rate pass-through to CPIF by shock and on average across 20 quarters, for the alternative model in Sweden

In Figure C.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 exchange rate pass-through to border prices is incomplete and the one to consumer prices is lower than the one to border prices.[36] Our results are thus in line with earlier literature, as we find that 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

[36] 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 producer versus local currency pricing, the level of competition in the industry that can induce pricing-to-market, the perceived persistence of the shocks hitting the economy and firms' hedging strategies against exchange rate movements.

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

Hence, the robust findings between this model and the benchmark model are the following: 1) the role of the demand shocks in generating negative 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 pass-through. Finally, the last two results point to the difficulty of relying on "rules-of-thumb", given that the shock-dependent measures of exchange rate pass-through can be very different from the average one.

C.3 Comparison with Forbes et al. (2018)

As a direct comparison with the specification in Forbes et al. (2018), we have considered the alternative model with import prices and omitted the sign restrictions on global supply shock described in section C. In this way, the identifying restriction for the global shocks is simply the zero long-run restriction for the global demand shock. Comparing the impulse responses to the global shocks of this model (Figures C.9 - C.10) with the ones of the original model, we notice that the responses are much more imprecise, with large bands around zero. Hence, also the pass-through to import and consumer prices features uncertainty bands around zero. Moreover, the impact of both shocks on the GDP has ambiguous sign, thus we can just define these shocks as temporary and persistent global shocks, like in Forbes et al. (2018), instead of demand and supply shocks. In terms of CERPT, we can compare Figure C.11 and C.12 with Figures C.7 and C.8. With this model we find no negative pass-through to import prices after any shock, and most of the shocks have a higher pass-through. In terms of consumer prices, we still find a negative pass-through after the local demand shock. The global temporary shock features a negative pass-through, but the probability bands include zero. The global persistent shock has a small positive pass-through, but the probability bands are still large. If we compare these results with Forbes et al. (2018), the model with Swedish data delivers an even more imprecise identification of the global shocks. At the same time, those shocks are very important for fluctuations of the Swedish Krona. Note that the probability bands around the pass-through for the global persistent shock in Forbes et al. (2018) are also large around zero.

This sensitivity exercise clarifies our twofold contribution to the literature. For small open economies with a business cycle closely linked to the rest of the world, a clear identification of the global shocks is important and this is achieved with our proposed set of identifying restrictions in the baseline model. Moreover, the negative pass-through following a global demand/transitory shock is not driven by our identifying restrictions.

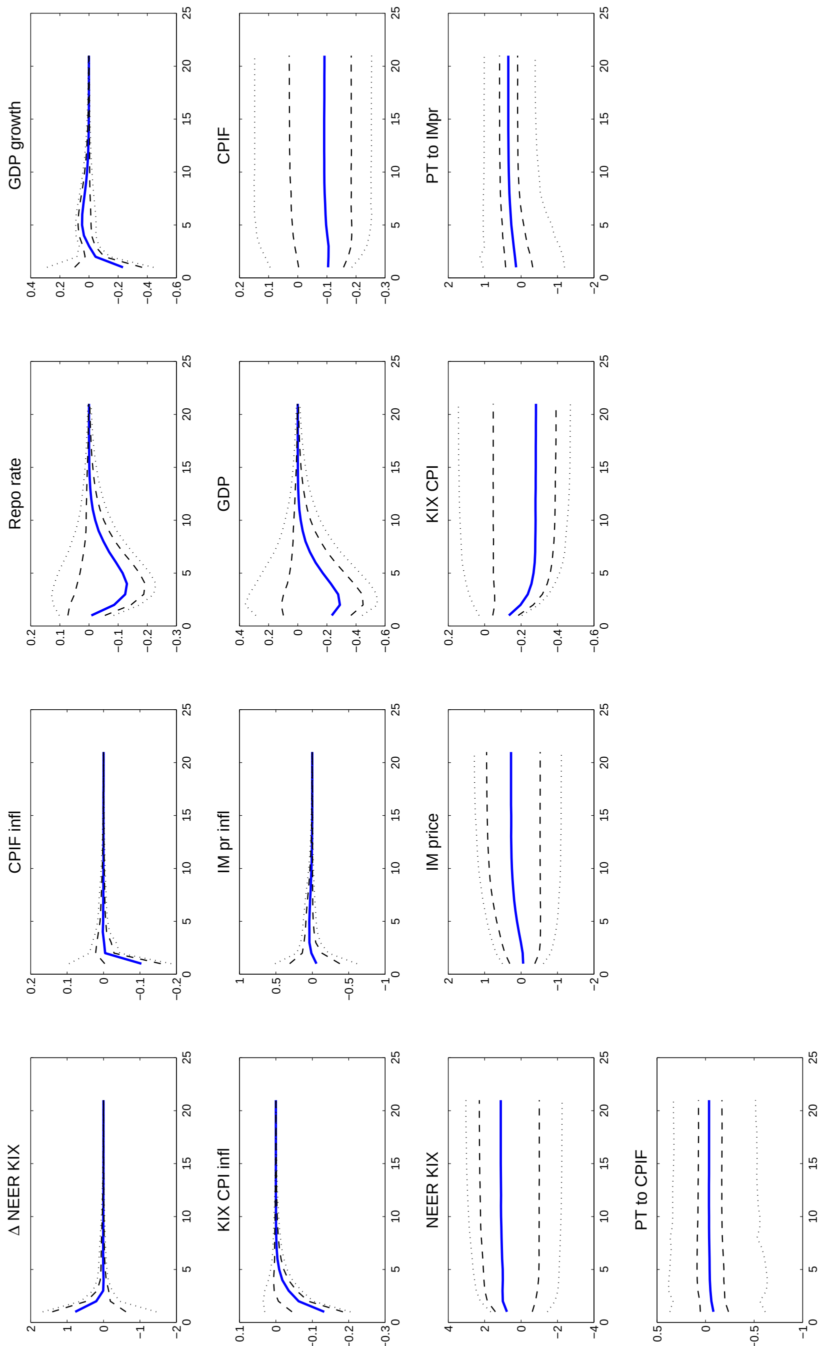

Figure C.9: Impulse responses to a global temporary shock based on the alternative identification in Forbes et al. (2018). The graphs report the median impulse response (solid line) with the 68 percent interval (dashed lines) and the 90 percent interval (dotted lines). The responses are rescaled to cause a depreciation of the Swedish Krona by 1 percent after 4 quarters in the median case.

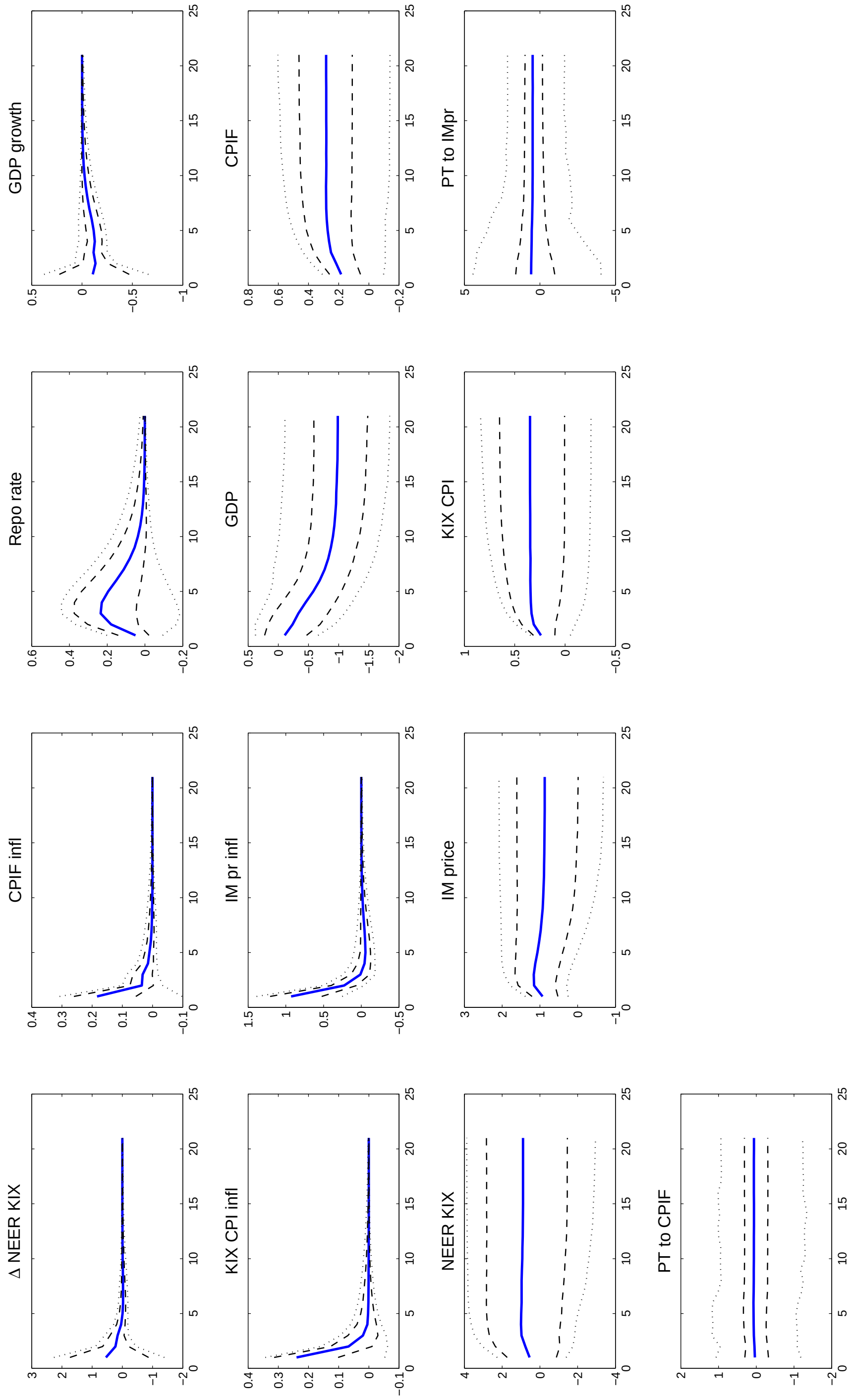

Figure C.10: Impulse responses to a global persistent shock based on the alternative identification in Forbes et al. (2018). The graphs report the median impulse response (solid line) with the 68 percent interval (dashed lines) and the 90 percent interval (dotted lines). The responses are rescaled to cause a depreciation of the Swedish Krona by 1 percent after 4 quarters in the median case.

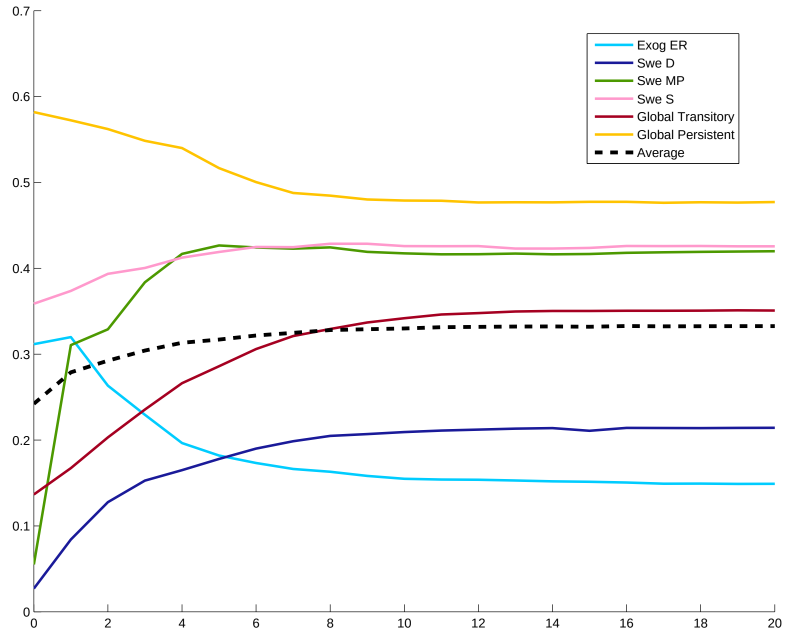

Figure C.11: Exchange rate pass-through to import price deflator by shock and on average across 20 quarters, for the alternative model based on Forbes et al. (2018) in Sweden.

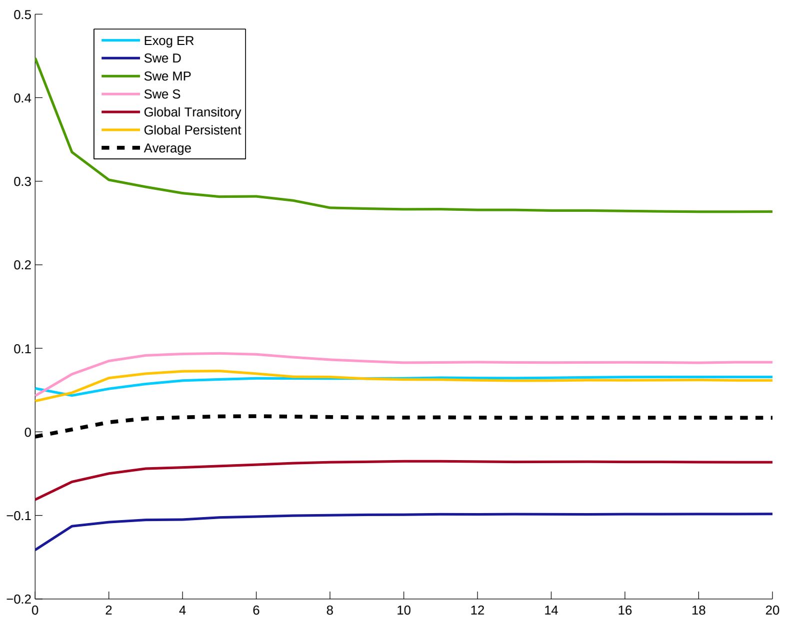

Figure C.12: Exchange rate pass-through to CPIF by shock and on average across 20 quarters, for the alternative model based on Forbes et al. (2018) in Swede.

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