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Boris Blagov[1]

Exchange Rate Uncertainty and Import Prices in the Euro Area

Abstract

This paper analyses the effects of exchange rate uncertainty on the pricing behaviour of import firms in the euro area. Uncertainty is measured via the volatility of the structural shocks to the exchange rate in a non-linear VAR framework and is an important determinant of import prices. An increase in exchange rate uncertainty is associated with a fall in prices on average, which suggests that the exchange rate risk is borne by the importers. The analysis utilizes a dataset on industrial import prices, disaggregated by origin of imports. Controlling for intra- and extra-euro area trade is important.

JEL Classification: C11, C22, F31

Keywords: Exchange rate uncertainty; exchange rate pass-through; non-linearities; import price inflation; extra-euro area trade

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1 Boris Blagov, RWI. – *I would like to thank Roland Döhrn, Steffen Elstner, Stefan Schäfer, Matthias Hartmann, Zeno Enders, and the participants of the research seminar of the German Central Bank, the 19th IWH-CIREQ-GW Macroeconometric Workshop, as well as Horia Guias and Svenja Elsner for the excellent research assistance.–* *All correspondence to: Boris Blagov, RWI, Hohenzollernstraße 1/3, 45128 Essen, Germany, e-mail: boris.blagov@rwi-essen.de*

1 Introduction

The extent to which exchange rate fluctuations affect the firms' pricing behaviour is an important topic for monetary policy as it is another potential channel for inflation. Importers and exporters face exchange rate risk, and both changes in the level as well as of the volatility of the exchange rate can influence the profit margins and hence be a key determinant of firms' prices.

How changes in the level of the exchange rate relate to changes in the import prices is characterized by the exchange rate pass-through (ERPT). The concept, almost deceptively simple to define, has proven highly elusive to pin down empirically. A large number of studies have investigated the ERPT and the estimates vary across countries, periods, and goods. These differences have been attributed to a number of factors ranging from time-varying pass-through and non-linearities to misspecification and data availability. A broad consensus in the literature is that the ERPT in most advanced economies is rather low, it is time-varying, and it has been on the decline in recent times.[1]

Notably, exposure to exchange rate risk may also result from the variatibility of the exchange rate and the uncertainty surrounding it. However, even within simpler theoretical models the nature of the relationship between import prices and exchange rate uncertainty is unclear.[2] For example, earlier literature based on partial equilibrium models suggests that prices could either rise or fall following an increase in the volatility of the exchange rate shocks (e.g. Clark, 1973; Hooper and Kohlhagen, 1978; Canzoneri, 1984; Froot and Klemperer, 1989; Gagnon, 1993). Within this framework the important determinant is who bears the exchange rate risk. If it is borne by importers, import demand and prices fall, while if the exporters bear the risk, prices rise to accommodate possible negative exchange rate developments. Furthermore, exporting goods to a foreign country could be seen through a real option framework. Producers may decide not to export to a country if it is not profitable. Moreover, non-domestic firms could also seek to exploit exchange rate volatility and uncertainty, if they have the option. Thus, import prices could ether fall or rise following an increase in the volatility, a result driven by violations of the law of one price and arbitrage opportunities (Canzoneri, 1984; Franke, 1991; De Grauwe, 1992). Empirical analyses have supported the ambiguousness in the relationship. For example Kroner and Lastrapes (1993) finds both positive and negative effects on prices.

[1] It has been argued, that the ERPT is time-varying and declining due to a variety of reasons. For example the low inflationary environment has been highlighted to play an important role in the pricing of imports. Analysing the ERPT through a microeconomic perspective suggests nominal rigidities such as menu-costs, currency invoicing, and the correlation structure of sales and costs as reasons for the decline in ERPT (Taylor, 2000; Bailliu and Fujii, 2004; Gagnon and Ihrig, 2004; Campa and Goldberg, 2005; Choudhri and Hakura, 2006; Bouakez and Rebei, 2008; Devereux and Yetman, 2010; Bussiere, 2013; Shintani et al., 2013; Choudhri and Hakura, 2015; Gopinath, 2015; Özyurt, 2016; Devereux et al., 2017; Turner and Wood, 2017; Enders et al., 2018). Another hypothesis regarding time-varying ERPT is that it is, in fact, rising during times of macroeconomic instability (Nogueira and León-Ledesma, 2011; de Bandt and Razafindrabe, 2014; Donayre and Panovska, 2016). Problems with misspecification and the sub-optimality of proxies for important determinants have also been highlighted (Goldberg and Knetter, 1997; Corsetti et al., 2008; de Bandt et al., 2008; Forbes et al., 2015).

[2] In theoretical models exchange rate uncertainty is defined as the volatility/standard deviation of the exchange rate shocks.

They use a reduced-form GARCH-in-mean model for a number o OECD members and find that exchange rate volatility effects are heterogeneous across countries, being statistically significant only for Japan and the United Kingdom. Cushman (1983) finds insignificant effects, echoing the findings of Gagnon (1993). Anderton and Skudelny (2001) use pooled IV estimator and find limited effects of exchange rate uncertainty on prices. More recent works have also highlighted the relevance of the second moments of the exchange rate, particularly focusing on its effects on the ERPT (Corsetti et al., 2008; Frankel et al., 2012; Ozkan and Erden, 2015).

Given the ambiguity in the theoretical relationship between exchange rate risk and import prices we set out to investigate it empirically. We define the exchange rate uncertainty as the volatility of the structural shocks to the exchange rate, which we extract in a structural VAR framework with stochastic volatility, where the variation of the shocks enters as a potential determinant in the VAR equations a lá Mumtaz and Zanetti (2013).[3] The framework provides several advantages that make it particularly suitable to this question. First, VARs are data-driven models that introduce as few restrictions between the variables as possible, which is desired given the premise of the theoretical predictions.[4] Second, as pointed out by Forbes et al. (2015), in the context of exchange rate pass-through shock identification matters. Our structural decomposition allows us to address potential problems that arise in reduced-form models and give a meaningful interpretation to the conditional volatility. Moreover, our measure of exchange rate uncertainty is endogenous to the exchange rate series, thus allowing for a feedback loop within the model.

We carry out the analysis using a novel dataset on industrial import prices in the euro area and some of the largest economies available from Eurostat.[5] The data reflect actual industrial import prices at monthly frequency, and thus provides sufficient number of observations to employ our non-linear methods. More importantly, the price index is available for intra- and extra-euro area trade separately, which can help alleviate potential bias when it comes to ERPT estimates.[6] A further advantage of the dataset is the availability of sub-components of the price index. It has been highlighted in the literature that the relationship between the exchange rate dynamics and import prices differs across industries (de Bandt et al., 2008), thus we can use these data to gain further insight into the interplay between import prices and exchange rates.

Our findings contribute to the literature in three ways. We show that exchange rate uncertainty is an important determinant of import prices in the euro area. On average an increase of the exchange rate uncertainty leads to a fall in import prices. This decline is mainly driven by a decrease in the prices of intermediate goods. On the contrary, consumer and capital goods' prices

[3]This definition coincides with popular definitions of uncertainty as the conditional volatility, i.e. the unforcastable component of a series (e.g. Jurado et al., 2015). While the formal definition will be presented in Section 3, we will use the terms uncertainty, volatility, and conditional volatility interchangeably.

[4]Shock identification still requires the introduction of additional assumptions. Our results, however, prove highly robust to alternative specifications.

[5]To our knowledge the dataset has been used so far in the ERPT context only by de Bandt and Razafindrabe (2014) and Özyurt (2016).

[6]A significant portion of euro area trade is within the Eurozone members.

either rise or are unresponsive. Following the theoretical literature this suggests that exchange rate risk is borne by the importers of intermediate goods and by the exporters of consumer and capital goods. Furthermore we find that the effects on import prices from extra-euro area trade are more pronounced than on their intra-euro area trade counterparts. This shows that a bias in the estimates may arise if one uses the aggregate import price index. However, third market effects are also present, which alleviates the bias.[7] Finally, the country specific analysis highlights the prevalent notion in the literature of a large degree of pricing behaviour heterogeneity across countries. Moreover, the effects of uncertainty vary across product groups and origin of imports.

The paper is structured as follows. In the next section we present our dataset and compare it with the ERPT literature to highlight the gains from using disaggregation by origin of imports. In Section 3 we lay down the econometric framework for the extraction of the measure of exchange rate uncertainty and present and discuss our findings on the interplay between import prices and exchange rate uncertainty. In Section 4 we discuss different specifications of the model to test the robustness of the findings. Section 5 concludes.

2 Data and specification

The goal of this section is lay down the fundamentals for our analysis on the effects of exchange rate uncertainty on the pricing behaviour of import firms. To this end we present our dataset in the context of the large literature on ERPT and discuss the most important determinants of import prices.

We utilize an industrial import price index dataset contained in Eurostat's short term business statistics. The series start in 2005 (for most countries) and are available at monthly frequency, presenting a comfortable amount of observations to work with. They are, however, not reported for all members. The countries covered are the Euro Area 19 aggregate, Germany, France, Italy, Spain, Netherlands, Greece, Slovakia, and Lithuania.[8] The data reflect actual transaction prices including discounts (i.e. not list prices). They take into account cost, insurance and freight at the national border of the importing country (excluding duties or import taxes), and price determining qualities of the imported products (e.g. service and guarantee conditions). Moreover, they are recorded at the transfer of ownership, and are expressed per unit of goods.[9]

[7] Third market effects in the ERPT context appear when the appreciation/depreciation of a third currency affects the prices of competitors, thus forcing both domestic firms and importers from other countries to adjust their prices. For example, the price of a German car in the United States might not only depend on the Euro/U.S. dollar exchange rate but also on the Japanese Yen/U.S. dollar rate, since Japanese cars are direct competitors in the U.S. market.

[8] Data for Lithuania and Slovakia start in 2009 and 2015. Both countries have adopted the Euro later, hence they are excluded from the analysis.

[9] This is in contrast to unit value indices (UVI), which are expressed as price per tonne, e.g. a price index for personal computers is tracked per unit of weight and hence reflects not only price changes but also accounts for quantity and quality variations over time.

The dataset tracks price development of an array of goods in multiple industries based on the CPA classification/NACE Rev.2 classes B, C, and D. These products are then grouped together in end-use categories which constitute the Main Industrial Groupings (MIG) and further aggregated to a composite index.[10] In this study we analyse the following indices: Composite import price index (CMP), consumer goods (CNS), capital goods (CAP), and intermediate goods (NTR) and omit the energy index, mainly due to the its dependence on the commodities markets, where prices are dominated by the dynamics of the U.S. dollar.

A notable feature of the data is that it is available for intra-euro area imports (*intra*), extra-euro area imports (*extra*), and as an aggregate series (*agg*). Intra-euro area trade accounts for about 2/3 of the trade volumes within the European union (EU28).[11] This could result in a bias arising in ERPT estimates, since a large share of the dynamics of the import prices might not be explainable through changes in the exchange rate. Take as an example the following simplified reduced-form analysis, where changes of the log-import prices, Δp, are regressed on log-changes of the exchange rate, Δe, and other control variables.

$$\Delta p_t^{agg} = \alpha + \beta_1^{extra} \Delta e_t^{extra} + \beta_1^{intra} \Delta e_t^{intra} + controls + \epsilon_{1,t} \quad (1)$$

By definition $\Delta e^{intra} = 0$, hence β_1^{intra} is indeterminate. The aggregate price index is a (possibly time-varying) weighted average of the prices of intra- and extra-euro area imports, i.e. $p_t^{agg} = \lambda_t p_t^{intra} + (1-\lambda_t) p_t^{extra}$ with weight $0 \leq \lambda_t \leq 1$. Thus a large share of intra-euro area goods in the index might introduce a downward bias in β_1^{extra}. In the extreme, β_1^{extra} might not be explaining any variation in p_t^{agg} if $\lambda_t = 1$ and there are no third market effects present. However, if the series p_t^{intra} and p_t^{extra} are available, the following regressions may be used to understand the nature and magnitude of the bias:

$$\Delta p_t^{intra} = \alpha + \beta_2^{extra} \Delta e_t^{extra} + \beta_2^{intra} \Delta e_t^{intra} + controls + \epsilon_{2,t}, \quad (2)$$

$$\Delta p_t^{extra} = \alpha + \beta_3^{extra} \Delta e_t^{extra} + \beta_3^{intra} \Delta e_t^{intra} + controls + \epsilon_{3,t}, \quad (3)$$

For example, if we find that for the origin specific coefficients $\beta_3^{extra} > \beta_2^{extra}$ it would follow from equation (1) that β_1^{extra}, which in the standard regression will be interpreted as a short-run ERPT coefficient, is a decreasing function of the share of intra-euro area goods in overall trade (λ). Thus, a rising λ_t could lead to the conclusion that the ERPT is time-varying when it was in fact the composition of imports that has shifted. Since in our dataset those series are available, we use them provide further insight into the interplay between intra- and extra-euro area trade prices and the exchange rate dynamics.

[10] For a full list of the included products and groupings please refer to the Appendix. For the relation between the CPA and SITC classifications see de Bandt and Razafindrabe (2014).

[11] See Figure 5 in the Appendix for the evolution of intra- and extra-euro area trade shares in the EU28.

2.1 Choosing the main determinants of imports prices

Controlling for the main determinants of import prices is of utmost importance in order to study the effects of exchange rate uncertainty effectively, as to reduce a potential omitted variable bias. For this we turn to the large empirical literature on ERPT where choosing the correct control variables is equally important. The classical framework for this analysis is an estimation equation of the following form (e.g. Campa and Goldberg, 2005)

$$\Delta p_t = \alpha + \sum_{i=0}^{n_e} \beta_i \Delta e_{t-i} + \sum_{i=0}^{n_c} \gamma_i y_{t-i} + \sum_{i=0}^{n_y} \delta_i \Delta c^*_{t-i} + \sum_{j=1}^{n_p} \zeta_j \Delta p_{t-j} + \varepsilon_t. \tag{4}$$

Aside from the exchange rate, e, the literature typically includes three key control variables: *(i)* domestic demand proxy, y; *(ii)* foreign producers' costs proxy, c^*; *(iii)* omitted product specific qualities, lagged p; as well as a constant, α, and a normally distributed error term, $\varepsilon_t \sim N(0, \sigma^2)$.

For e, we take the nominal effective exchange rate (NEER) defined in quantity notation, such that an increase implies an appreciation of the domestic currency. For the domestic demand variable we choose industrial production, which is consistent with the use of industrial import prices and is also collected at a monthly frequency. The foreign producers' cost variable choice is not straightforward. Costs are a crucial determinant in price setting. However, most series candidates are proxies and do not capture producers' costs directly. The literature is split with regard to what proxy is best. One approach is to use foreign unit labour costs (ULC) (e.g. Bailliu and Fujii, 2004). The economic argument here is that producers choose a destination specific mark-up and thus a ULC is the relevant explanatory variable. It has been argued, however, that in common markets exporting firms might place the same mark-up both domestically and abroad. In that case the cost structure would be well accounted for via a foreign price series directly (know as "pricing-to-market" or PTM. See e.g. Marston, 1990; Goldberg and Knetter, 1997). Research has shown that in certain situations both proxies can perform equally well and both are associated with certain disadvantages (Corsetti et al., 2008).

In this paper we follow the PTM literature argument and use foreign prices for the producers' cost proxy, which is in our view well suited for the European Single Market. However, we have explored both options and our results remained quantitatively and qualitatively similar. Nevertheless, we find that in general the ULC specification for c^* is not as statistically informative. Preliminary correlation analysis showcased low correlation between c^* and p for many countries. The estimated coefficients of the ULC proxy (δ_i) were often insignificant and variance decomposition analysis exhibited low explanatory power of the proxy over the import prices. In that specification the own lags of import prices become statistically significant and especially relevant. On the contrary, in the PTM specification δ_i was in many instances highly significant and carried explanatory power in terms of variance decomposition over p, while own lags of import prices became less important. This suggests that the ULC specification suffers from omitted variable bias, which is corrected for using lagged prices and can explain why our findings remained similar.[12] Another potential pitfall of the ULC specification is that unit labour costs are available on quarterly frequency, thus interpolation was needed to construct c^*.

To construct a trade-weighted producers' cost proxy we utilize the real effective exchange rate, Q, based on the consumer price index (CPI), in logarithms: $q = e + cpi - cpi^*$, where cpi^* is the natural logarithm of the trade weighted foreign price level. Given series for q, e, and cpi it follows that $c^* = cpi^*$.[13]

2.2 Revisiting the ERPT in the euro area

To give some context of the import price dataset we carry out a reduced-form analysis on the ERPT. This is done primarily to facilitate some discussion how our data relate to other studies and therefore we do not deviate from the standard model before we jump to a non-linear framework in the next section. We estimate equation (4) per country for each combination of import price index and origin of products, i.e. $p^{j,k}$ for $j \in \{CMP, CNS, NTR, CAP\}$ and $k \in \{agg, intra, extra\}$. The data ranges from January 2005 to September 2018.[14]

Equation (4) is an autoregressive distributed lag model of order n_x, $x \in \{e, w, p, y\}$. The estimate for short-run ERPT is defined as $\hat{\beta}_0$ and the long-run pass-through (LR-ERPT) estimate by $\sum_i \hat{\beta}_i/(1 - \sum_j \hat{\zeta}_j)$. Therefore, the LR-ERPT is a function of the lags of both e and p and choosing an arbitrary lag-order has direct impact on the results. To reduce the influence of the choice we take a formal approach through statistical testing and use information criteria (IC) to choose the optimal number of lags, n_x. We present the results with the Schwarz IC (SIC). Using the Akaike IC (AIC) delivers remarkably similar estimates both qualitatively and quantitatively, they are reported in Table 2 the Appendix.

Table 1 shows the point estimates of LR-ERPT following a 1% appreciation of the nominal exchange rate.[15] Starting from the composite index, the long-run pass-through is on average significant for the euro area as a whole, Germany, Italy, Spain, and the Netherlands and insignificant in France and Greece. In all countries the pass-through is incomplete and rather low, thus we can reject the notion of producer currency pricing. Compared to the other studies estimated pass-through is lower (in absolute values) and in some cases insignificant.[16] On average the aggregate index for intermediate goods seem to have the highest pass-through, while capital goods are not much susceptible to exchange rate changes.

The disaggregation by origin of products provides particular insight into the import price dy-

[12] The results are available upon request.

[13] An argument against using the CPI is that it might not be perfectly reflecting the developments of industrial import prices abroad. An alternative specification would be to use the import prices in the construction of the proxy instead. However, the weights in q are based on the CPI.

[14] For the data sources see the Appendix, Section 6.3.

[15] We provide long run estimates, since other studies are in quarterly frequency and short-run estimates are not directly comparable.

[16] A selection of ERPT papers and long-run estimates is available in the Appendix, Section 6.5.

Table 1: Long-run exchange rate pass-through estimates.

Endogenous variable	EA	DE	FR	IT	ES	NL	GR
Composite price index							
p^{agg}	-0.14*	-0.33*	-0.10	-0.21*	-0.38*	-0.38*	-0.03
p^{intra}	-0.07*	-0.15*	-0.04	-0.12*	-0.10*	-0.24*	0.00
p^{extra}	-0.21*	-0.38*	-0.15	-0.34*	-0.73*	-0.46*	-0.11
Consumer goods prices							
$p^{CNS,\,agg}$	-0.19*	-0.37*	-0.19*	-0.13*	-0.71*	-0.57*	-0.07
$p^{CNS,\,intra}$	-0.10*	-0.12*	-0.08	-0.02	-0.13*	-0.47*	0.00
$p^{CNS,\,extra}$	-0.23*	-0.49*	-0.39*	-0.41*	-1.31*	-0.70*	-0.17*
Intermediate goods prices							
$p^{NTR,\,agg}$	-0.21*	-0.43*	-0.20*	-0.57*	-0.57*	-0.23*	0.05
$p^{NTR,\,intra}$	-0.12*	-0.22*	0.06	-0.20	-0.09	-0.11	0.12
$p^{NTR,\,extra}$	-0.26*	-0.60*	-0.23*	-0.63*	-1.00*	-0.48*	-0.15
Capital goods prices							
$p^{CAP,\,agg}$	-0.13*	-0.27*	-0.18*	-0.16*	-0.38*	-0.53*	-0.01
$p^{CAP,\,intra}$	-0.04*	-0.06*	-0.09*	-0.03	0.00	-0.40*	0.00
$p^{CAP,\,extra}$	-0.26*	-0.41*	-0.28*	-0.45*	-0.73*	-0.65*	-0.08*

Estimates of long-run ERPT, changes to import prices following a one percent appreciation of the nominal exchange rate. CMP: The composite index; CNS: Consumer goods index; NTR: Intermediate goods index. CAP: Capital goods index; Sample size: 2005M1:2018M9. The countries, given by the 2-digit ISO code, are Euro Area 19, Germany, France, Italy, Spain, the Netherlands, and Greece. A star (*) indicates significance at the 5% level.

namics. There is evidence for third market effects, seen in the significant responses of intra-euro area goods' prices to changes in the NEER. They are smaller than the aggregate ERPT estimate and are not present in all countries and all types of goods. The strongest effects are in the Netherlands, specifically in consumer and capital goods' prices. The estimated ERPT for extra-euro area imports is high, particularly for intermediate goods. We see that the aggregate estimates area always between the intra- and extra-euro area trade estimates, i.e. the effects on the different prices have clear structure, from strongest to weakest: $p^{extra} > p^{agg} > p^{intra}$. Thus, we conclude that aggregate estimates do exhibit a downward bias.

Finally, the table highlights a high degree of heterogeneity on several dimensions - within and across member states. In each country different product groups have different degrees of pass-through. This is in line of the findings of de Bandt et al. (2008), who show similar results with UVIs and SITC product groupings in a panel setting. Thus, some industries are more susceptible to exchange rate shocks than others. A notable exception is Greece, where no ERPT is detected. Across countries we find a higher degree of pass-through in the Netherlands and Spain than in the other member states. We find that the intermediate industrial goods are the most susceptible to exchange rate fluctuations. Compared to other studies, industrial import prices seem to exhibit a lower pass-through. They are closer to the estimates by Warmedinger (2004) and Özyurt (2016) and much lower than de Bandt et al. (2008) who use UVI. Thus we may hypothesise that the estimated effects of exchange rate uncertainty, to which we turn next, are on the lower-end of the spectrum and larger in the aggregate.

3 Exchange rate uncertainty and import prices

Having laid out the foundation of modelling the import prices we now turn to analysing the effects of exchange rate uncertainty, which we define first. We suggest an uncertainty measure based on a structural vectorautoregressive model (SVAR), which is used to identify the shocks to the exchange rate. The model is extended with stochastic volatility of the structural shocks, which enters the equations in level as in a GARCH-in-mean framework. The resulting volatility series is the adopted measure of uncertainty. Essentially, this is the stochastic conditional variance of a structural model, where feedback between the conditional variance and the model parameters is explicitly accounted for. The specification allows us to analyse the effects of changes to the volatility of the structural shocks on the variables and specifically to the import prices.

The framework has been proposed by Mumtaz and Zanetti (2013) and is particularly suitable for this analysis due to a variety of reasons. First, conditional volatility as an uncertainty proxy has been a staple in the literature, especially in financial and international economics, where a plethora of autoregressive heteroskedasticity (ARCH) methods have been employed to model the observed volatility in the data, especially the exchange rate dynamics (Baillie and Bollerslev, 1989; Kroner and Lastrapes, 1993). Specifically the GARCH-in-mean models have also been employed in the ERPT literature (Kroner and Lastrapes, 1993; Straub and Tchakarov, 2004; Grier and Smallwood, 2013; Ozkan and Erden, 2015). Intuitively, the conditional volatility captures the variability of the unforcastable component of a time series, which is a common definition of uncertainty (Jurado et al., 2015). Second, the volatility measure is endogenous to the exchange rate series and may be estimated jointly with the model parameters. Third, the VAR framework provides a flexible foundation for the analysis by introducing as few restrictions as possible.

3.1 Econometric framework

The model proposed by Mumtaz and Zanetti (2013) is a SVAR, where the second moments of the system are treated as additional regressors. Mathematically it is given by the following form

$$Z_t = c + \sum_{i=1}^{n} \beta_i Z_{t-i} + \sum_{j=0}^{n_{ex}} \gamma_j \tilde{h}_{t-j} + \Psi_t^{1/2} u_t, \tag{5}$$

with $u_t \sim N(0,1)$ and $\Psi_t = A^{-1} H_t A^{-1'}$. Z_t collects the realizations of N variables at time t and $\tilde{h}_t = [h_{1t}, ..., h_{Nt}]$ denotes the log-volatilities of the structural shocks. These are identified via imposing restrictions through the matrix A, while H_t is a diagonal representation of $exp\{\tilde{h}_t\}$. The parameters n and n_{ex} denote the lags of the endogenous and exogenous variables, respectively.

The stochastic volatilities are given by transition equations in the form of AR(1) processes. In matrix form (Θ being a diagonal matrix)

$$\tilde{h}_t = \Theta \tilde{h}_{t-1} + \eta_t, \quad \eta_t \sim N(0, Q), \quad E_t(u_t, \eta_t) = 0. \tag{6}$$

As evident from eq. (5) the log-volatilities have an effect on the levels of the endogenous variables. Moreover, it has an effect on the estimated parameters, in the sense that uncertainty is a determining factor when estimating the relationships between the variables. Moreover an advantage of this framework compared to reduced-form models with stochastic volatility, such as the GARCH-in-mean model where the volatility also has an effect on the other parameters, is that $\tilde{h}$ refers to the log-volatility of the *structural* shocks. Thus, we may attach an interpretation to the innovation η_t: How do the variables react following an increase in the volatility of e.g. the exchange rate shocks? In this setting even if the exchange rate remains constant, second order effects could play a role for the pricing decision of firms.

Due to the presence of the volatility terms in eq. (5) the conventional maximum likelihood approach is not applicable. The model is estimated via Bayesian methods with Gibbs sampling, i.e. drawing the parameters iteratively from their conditional distributions.

The model parameters may be divided into several blocks based on their distributional assumptions. The reduced-form coefficients $B = [\beta, \gamma]$, the stochastic volatility block $\mathcal{H} = [H_1, ..., H_T]$ and its parameters Θ, and the contemporaneous responses A. In order to capture the heteroskedasticity introduced through the stochastic volatility an additional matrix, Q, is required at the estimation stage of B. To ease notation, we introduce Ω^{-i}, where $\Omega = [A, B, Q, \mathcal{H}, \Theta]$ collects all the parameter blocks and the superscript $-i$ denotes the exclusion of the i-th block such that $\Omega^{-B} = [A, Q, \mathcal{H}, \Theta]$.

To conduct inference we draw the i-th block from $p(i|\Omega^{-i})$. Given initial values for all parameters this process is as follows:

1. Conditional on $\mathcal{H}$, A may be drawn as a linear regression from $p(A|\Omega^{-A})$, given the form in eq. (6) in conjunction with the algorithm of Cogley and Sargent (2005).

2. The reduced-form parameters, B, are given by a linear regression with heteroskedasticity and may be estimated via GLS. Following Carter and Kohn (1994) we introduce stochastic volatility via a matrix Q, employ the Kalman filter for $t = 1, ..., T$ to get $\beta_{T|T}$ and $\gamma_{T|T}$ and draw the parameters from $p(\beta_{T|T}, \gamma_{T|T}|Q, \Omega^{-B,-Q})$.

3. Conditioning on the draws for B, Q may be drawn from an inverse Wishart distribution.

4. Given the reduced-form coefficients, the stochastic volatility estimation follows Cogley and Sargent (2005), where the draws for $\mathcal{H}$ may be obtained using a Metropolis-Hastings algorithm.

We estimate the model with the variables in eq. (4). The priors are initialised using a training sample of 35 observations (similar to Primiceri (2005) and Mumtaz and Zanetti (2013)) or roughly three-years at monthly frequency. The prior for the reduced-form coefficients is selected via a GLS estimation on the training sample. This is also the basis for the priors on $\tilde{h}$. For identification of shocks to the endogenous variables we use a lower-triangular Cholesky factorization. This choice is motivated not only by the literature but more by its simplicity given the already non-linear method employed. Regarding the ordering we put the import prices below the exchange rate, as is custom in the studies on ERPT, which is also consistent with eq. (4), however, our results prove robust to the permutation of those variables. The foreign producer cost proxy and domestic demand are positioned first, i.e. they do not react contemporaneously to prices or exchange rates.[17] It follows that $Z_t = [\Delta c_t^*, \Delta y_t, \Delta e_t, \Delta p_t]'$. It is important to note, that when we introduce a shock to the volatilities this propagates with immediate effect to all variables. The size of the effect is determined by γ in eq. (5). In that respect, conditioning on a volatility series the ordering of the variables is irrelevant.

The number of lags for the endogenous variables, n, is chosen as in the previous section via SIC. The lag order of the stochastic volatility, n_{ex}, also plays an important role for the impulse responses, as shown by Mumtaz and Zanetti (2013). Therefore we select n_{ex} via formal testing as well. We estimate the model with $n_{ex} \in [0, ..., 4]$ (note that index j in eq. (5) begins at 0) and test the residuals and the squared residuals for autocorrelation using the Ljung-Box test. We start at $n_{ex} = 0$ and continue until the test cannot reject H_0 of no autocorrelation. In all cases this is at $n_{ex} = 1$.

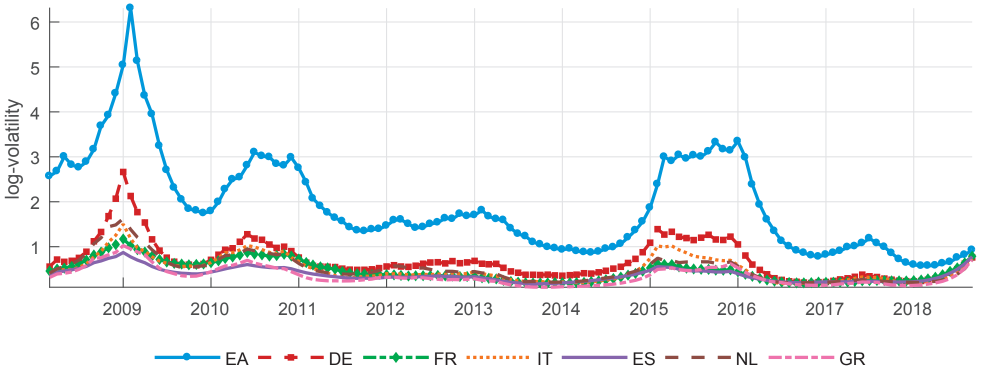
3.2 Empirical estimates of the exchange rate uncertainty

We present our uncertainty measure on Figure 1. It depicts the estimated stochastic volatility of the exchange rate shocks for the countries in our sample.[18] The series are highly similar in terms of dynamics because in all cases we use the NEER for e, which differs across countries only in terms of country-trade weights. The EA NEER is the most volatile since it includes the the highest amount of currencies. On the other end of the spectrum are Greece and the Netherlands. The main difference between the magnitude of the peaks is stemming from the volatility of the NEER series itself. Some countries trade more with partners that have stable currencies, which results in lower volatility of e. The profile of uncertainty series can be summarized for all countries by three notable episodes: the global financial crisis, the onset of the sovereign debt crisis, and the year 2015–2016, which was associated with a weakening of the Euro. The NEER depreciated by 10% while the U.S. dollar gained considerable strength in light of the presidential elections.

[17] The position of y relative to Δc^* is unimportant, since the primary object of interest is the response of Δp to a change in Δe. We nevertheless test for ordering y first with no apparent quantitative effects.

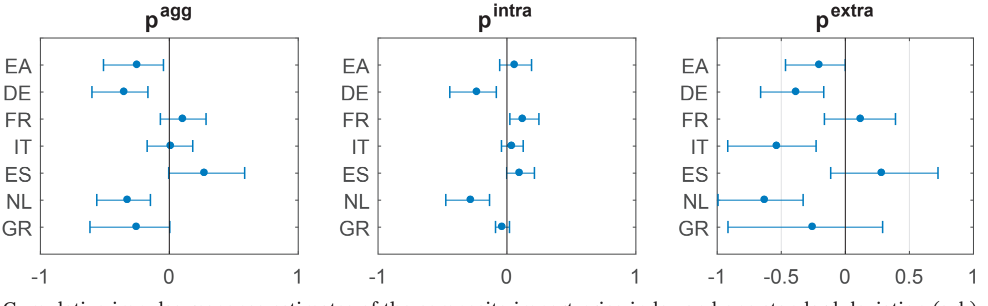
[18] In the interest of space we present the results for the aggregate composite index p^{AGG} only. However, the other estimates are similar.

Figure 1: Estimates of exchange rate uncertainty



Next we examine the effects of exchange rate uncertainty on import prices by introducing a shock of one standard deviation to the stochastic volatility series of e. The magnitude may be interpreted as the average historical size of an exchange rate shock. As evident from Figure 1, different countries have different exposure to exchange rate uncertainty. Therefore the shocks will not be comparable in size. On the other hand, normalising the shocks is not economically meaningful, given that they represent changes to log-volatility series.[19] We calculate the cumulative impulse response (CIRF) on prices 12 months after the initial shock as a measure of a long-run estimate of the uncertainty effects in import prices. Figure 2 depicts the estimates with probability intervals for the composite price index.

Figure 2: Response of the composite import price index after an exchange uncertainty shock.



Cumulative impulse response estimates of the composite import price index and one standard deviation (s.d.) probability intervals 12 months after a one s.d. shock to the volatility of exchange rate shocks from a VAR a lá Mumtaz and Zanetti (2013). Countries denoted by the 2-digit ISO code. Aggregate prices (*agg*), prices of euro area imports (*intra*), and non-euro area imports (*extra*).

Not conditioning on the origin of imports we find that on average prices fall in the euro area, in Germany, in the Netherlands, and in Greece and they do not react to exchange rate uncer-

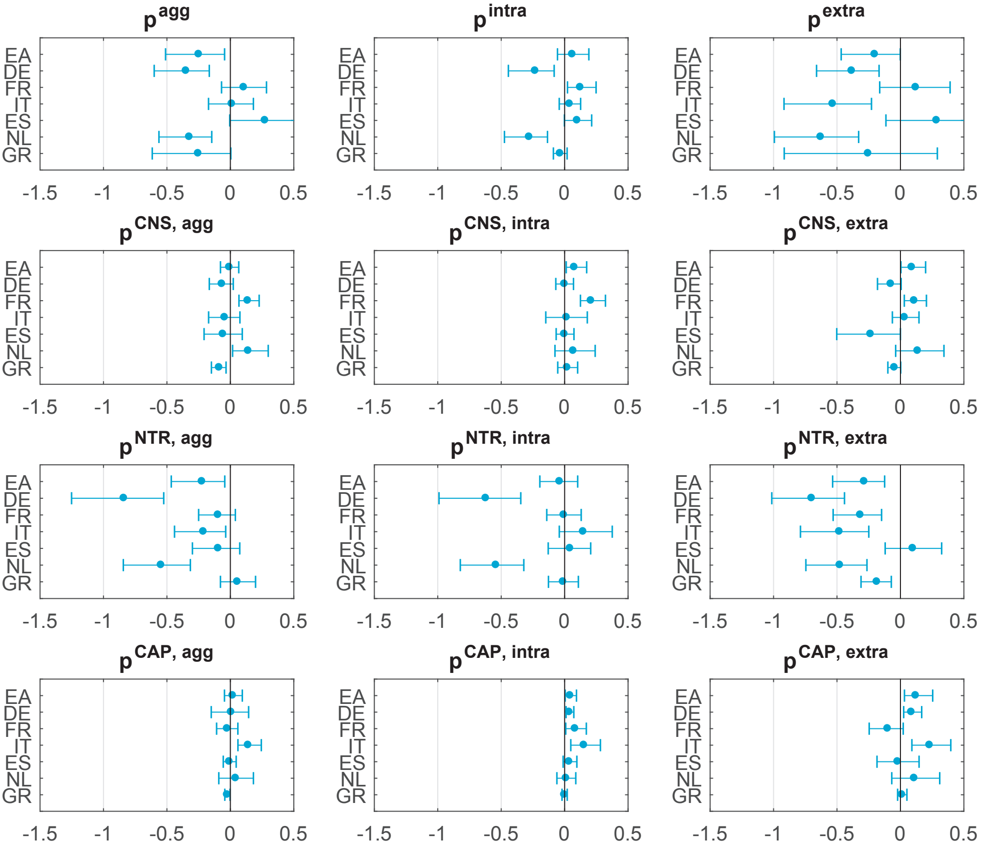
[19]It should also be noted that normalising the shocks to the same size in fact does not facilitate comparison across countries. For example, the effects of exchange rate uncertainty will be underestimated for countries that trade with third parties that have more fluctuating currencies, since the typical uncertainty shock will be on average higher in magnitude. Conversely the effects will be overstated for countries with a more stable NEER.

tainty in France and Italy. In Spain we find marginally significant inflation in import prices. Disaggregating the effects by origin of imports offer particularly interesting insights into these results. The findings for the euro area are primarily driven by extra-euro area trade, which is to some extent also true for Germany and the Netherlands. Exchange rate uncertainty does not seem important for French import prices, if not for a small but significant positive third market effect. In Italy extra-euro area prices seem to adjust following uncertainty shocks but not enough to push the changes in the aggregate index significantly away from zero. In Greece the aggregate index is marginally significant, yet neither intra- nor extra-euro area trade appears to be reacting to exchange rate uncertainty, thus the p^{agg} estimates are probably the result of a statistical artefact. Prices in Spain do not vary significantly, apart from minor third market effects prices. However, the general direction of the point estimates is different compared to the rest of the euro area members.

The availability of individual product groups allows us to gain further intuition behind the driving force of the empirical findings. Figure 3 plots the CNS, NTR, and CAP indices, along with the composite index from Figure 2. The composite index is depicted once more to allow for easier comparison to the sub-indices, which show larger variation and therefore require a different scale. There are three key points to be taken away.

First, intermediate goods' prices appear to be the major force behind the fall in the composite index. They react stronger on average and also show a heterogeneous impact between intra- and extra-euro area trade. With the exception of Germany and the Netherlands, p^{intra} do not react to exchange rate uncertainty shocks. This finding is also in line with Table 1, where the estimated pass-through is highest for the intermediate goods. Second, the impact on consumer and capital goods' prices is not consistent across countries. In most cases exchange rate uncertainty does not play a role. In the other instances we see a subsequent price increase, in contrast to intermediate goods. Third, the cases where the composite index reacts positively are instances where either consumer or capital goods increase and intermediate goods are unaffected by uncertainty. This is true for Spain and in France for intra-euro area trade. The only exception is the Netherlands, where the a fall in the intermediate goods, which has bigger effect than the opposite price dynamics of consumer goods.

Figure 3: Responses of import prices' sub-indices following an exchange rate uncertainty shock.



Cumulative impulse response estimates of the composite import price index, consumer goods import price index (CNS), the intermediate goods price index (NTR), and the capital goods import price index (CAP) and one standard deviation (s.d.) probability intervals 12 months after a one s.d. shock to the volatility of exchange rate shocks from a VAR a lá Mumtaz and Zanetti (2013). Countries denoted by the 2-digit ISO code. Aggregate prices (*agg*), prices of euro area imports (*intra*) and non-euro area imports (*extra*).

3.3 Discussion

An important question that Figure 3 raises is why is there such heterogeneity across the estimates? The theoretical literature on exchange rate uncertainty and import prices suggests several factors at play that contribute to the ambiguity of the pricing behaviour.

The first important aspect is the definition of the import prices, which reads "actual transaction prices, including discounts, recorded at the transfer of ownership". Thus, what is observed is the negotiated price between exporter and importer and subsequent changes over time could stem both from renegotiation on the importer part, as well as from the exporter part. The question then arises, how does risk enter the equation and on which side?

In standard macroeconomic models firms are taken as risk-neutral since there is much evidence to supports this view. However, it has been shown that exchange rate uncertainty may have an effect on trade even with risk-neutral firms. For example, on the producers' side exporting might be viewed as a (costly) option, since international transactions involve significant sunk costs with the opportunity costs being the participation at the domestic market. Thus, producers may decide not to export to a foreign country if it is not profitable (Dixit, 1989; Krugman, 1989). Moreover, non-domestic firms could also seek to exploit exchange rate volatility and uncertainty for profitability (Canzoneri, 1984; Franke, 1991; De Grauwe, 1992). Hence, to understand the relationship with uncertainty better the literature has drawn on models with risk aversion.

Which side bears the risk is the main determinant of the pricing behaviour (Clark, 1973; Hooper and Kohlhagen, 1978; Franke, 1991). If it is on the the producer part, prices will rise with excess volatility increasing as potential negative exchange rate developments erode the revenues and profits of the firm. This is essentially a second order effect of producer currency pricing, where exchange rate fluctuations are reflected one to one in price changes. On the other hand, the risk is on the importers' side import prices fall because import demand falls. In this line of argument we find that exchange rate risk in the euro area tends to be borne by importers of intermediate goods and by exporters in some isntances of capital and consumer goods. In most cases it affects the non-euro area imports the most. Large third market effects of exchange rate risk are present in Germany and the Netherlands.

Finally, it is worth noting that there are further determinants that could play a role, irrespective of the risk appetite of firms. Froot and Klemperer (1989) highlight the importance of the market structure and the market shares. For example firms in oligopolistic markets might increase or lower their prices when faced with exchange rate uncertainty depending on their market share and their perception of temporary and permanent shocks. In our framework, however, we cannot differentiate between these types of shocks in a structural manner.

4 Robustness of the findings

We assess the validity of our empirical framework using a variety of robustness checks. A prevalent notion in the ERPT literature is that estimates have been often found to be sensitive to the time span of the data. Moreover we use Bayesian analysis where the priors are set using a training sample, essentially amplifying potential effects of specific time period. Therefore, we explore this avenue more thoroughly first. Second, we analyse the effects of the multivariate framework on our findings by integrating the effects of the stochastic volatiltiy on prices from the second-order effects that may arise through the other variables. For example the exchange rate uncertainty is also having an effect on the level of the exchange rate, which itself is an important determinant of prices. While this is natural for a structural model, it is important how much of the observed decline in prices is due to exchange rate uncertainty directly and how much is a response to the subsequent changes in the exchange rate.

4.1 Training sample, prior analysis and the global financial crisis

The full data range is from 2005:M1 to 2018:M9. Using three years (36 months) for the training sample and accounting for the lag structure means that the estimation starts right before the global financial crisis. Given that the crisis was mirrored in global price declines it could be that we have omitted variable bias driving our results. Thus we carry out the following robustness analyses: *(i)* we exclude 2008 and 2009 from our estimates, that is we still use 2005–2008 as a training sample but then start the estimation from January 2010 in order to gauge the effects of the crisis; *(ii)* we include the global financial crisis in the prior by enlarging the training sample until the end of 2009 in order to gauge the weight of the prior. Qualitatively both cases do not change our findings, even quantitatively the posterior distributions of the estimates overlap.[20] Internalising the crisis does not yield any particular insights into the developments of the import prices, which suggests that the decline is well captured by the decline in domestic demand and foreign producers' costs.

4.2 Partial equilibrium effects

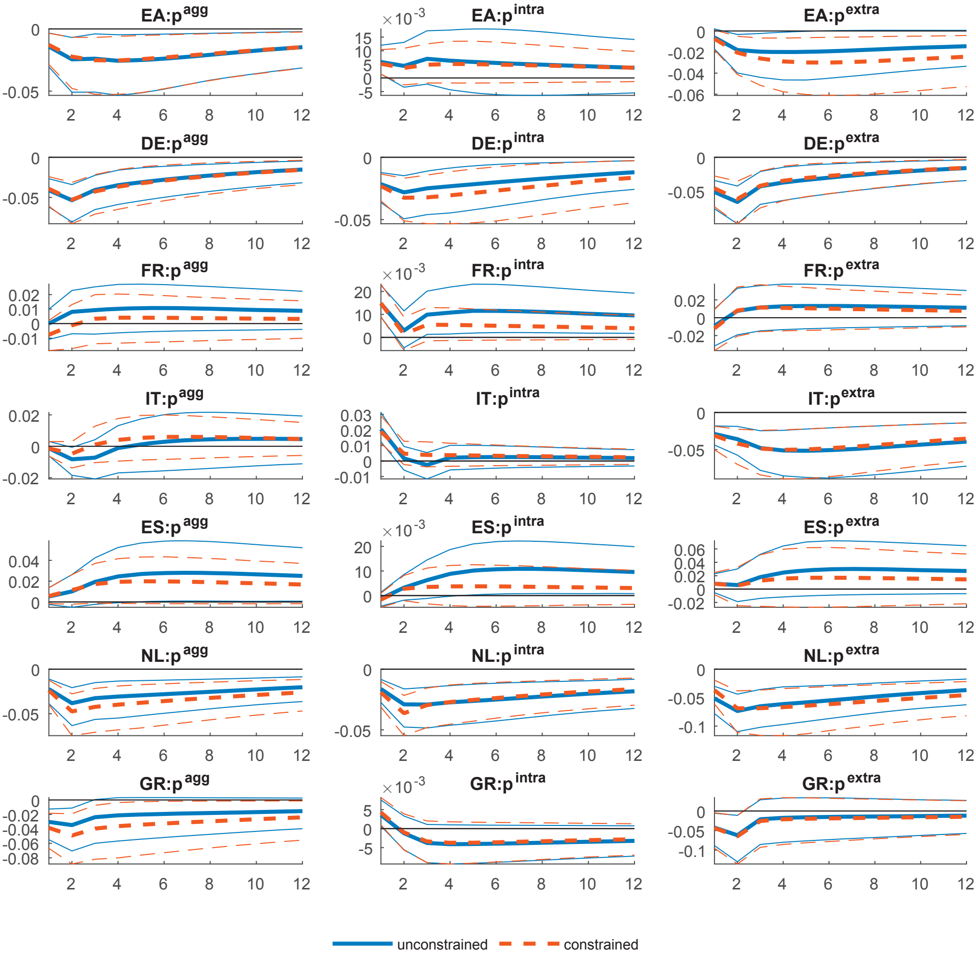
In the standard VAR framework all variables are interconnected. In our setup this is even more important, given that the exogenous variables have an impact on all endogenous variables simultaneously. This may be seen as a drawback, since the response of prices is also influenced by the responses of the other variables. At the same time, the stochastic volatility estimates are a product of a decomposition of the residuals in the regression, hence the implied volatility series would be different if one variable is substituted for another. In light of these two considerations it may be argued that the different responses of the import prices are simply a product of the remaining variables.

We test for this by integrating out the effects of the remaining variables from the IRFs. This is similar to conducting a partial equilibrium analysis in a single equation framework. We are looking at the change in import prices following a change in the volatility of the structural shock to the nominal exchange rate by holding all else equal. Figure 4 plots the responses of the composite price index from Section 3.2 along with the IRFs from the constrained model with the rest of the variables held constant. We find that at large the responses of the prices are due to their inherent dynamic and not explained by movements in the other variables. This also holds for the subgroups of the index.[21]

[20] Results are available upon request.

[21] In the interest of space we relegate the subgroups' IRFs to the Appendix, Section 6.8.

Figure 4: Impulse response functions: Constrained vs. unconstrained model



Response of the composite import price index for aggregate, euro area and non-euro are imports following a change to the volatility of the exchange rate shocks. Unconstrained model as laid out in the previous section, constrained model presents the response to prices following the volatility change all else held equal.

5 Conclusion

In this paper we explore the effects of exchange rate uncertainty on the pricing behaviour of firms using a monthly dataset on industrial import prices for the euro area and six of its members. Using a non-linear framework we show that second order exchange rate effects are an important determinant of import prices. In the face of increased exchange rate uncertainty intermediate goods' prices fall, while capital and consumer goods react either positively or none at all. Notably the response of intermediate goods' prices is strong and overwhelms the other developments leading to a price decline in the aggregate on average. The effects are the strongest in Germany and the Netherlands, both of which are heavily involved in international trade.

We find that controlling for intra- and extra-euro area trade highlights an important aspect of ERPT estimations. Disaggregating the price index by origin of imports reveals that euro area imports have little to no pass-through and bias the estimates of the aggregate downwards. Conversely, non-euro area ERPT is high and significant. These findings are mirrored when estimating the effects of exchange rate uncertainty, where imports from non-euro area countries react much stronger to exchange rate uncertainty shocks. Third market effects are present mostly in Germany and the Netherlands and to some extent in Italy when it comes to consumer and capital goods.

Overall we find that exchange rate non-linearities are an import part of the import price dynamics and that there is significant heterogeneity across the different types of goods. One of the more interesting questions that would have direct effects on our findings is the effect of exchange rate asymmetry when it comes to import prices. For example the effects of exchange rate uncertainty stemming from a prolonged expectation of a depreciation, such as during the European sovereign debt crisis, might be different from the expectation around prolonged depreciation, such as before the global financial crisis. The employed framework is does not incorporate asymmetric shocks and this question is left for future research.

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6 Appendix

6.1 Components of the Main Industrial Groupings

The following list has been adopted from Eurostat's short term business statistics information and provides the end-use categories (MIGs) based on the NACE Rev.2 classification, which refers to Mining and carrying (Category B of NACE Rev. 2.), Manufacturing (Category C of NACE Rev. 2.), Electricity, gas, steam and air conditioning supply (Category D of NACE Rev. 2.) and Water supply, sewerage, waste management and remediation activities (Category E of NACE Rev. 2.).

Intermediate Goods
- B07: Mining of metal ores;
- B08: Other mining and quarrying;
- B09: Mining support service activities;
- C10.6: Manufacture of grain mill products, starches and starch products;
- C10.9: Manufacture of prepared animal feeds;

- C13.1: Preparation and spinning of textile fibres;
- C10.6: Manufacture of grain mill products, starches and starc products;
- C10.9: Manufacture of prepared animal feeds;
- C13.1: Preparation and spinning of textile fibres;
- C13.2: Weaving of textiles;
- C13.3: Finishing of textiles;
- C16: Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials;
- C17: Manufacture of paper and paper products;
- C20.1: Manufacture of basic chemicals, fertilisers and nitrogen compounds, plastics and synthetic rubber in primary forms;
- C20.2: Manufacture of pesticides and other agrochemical products;
- C20.3: Manufacture of paints, varnishes and similar coatings,
printing ink and mastics;
- C20.5: Manufacture of other chemical products;
- C20.6: Manufacture of man-made fibres;
- C22: Manufacture of rubber and plastics products;
- C23: Manufacture of other non-metallic mineral products;
- C24: Manufacture of basic metals;
- C25.5: Forging, pressing, stamping and roll-forming of metal; powder metallurgy;
- C25.6: Treatment and coating of metals; machining;
- C25.7: Manufacture of cutlery, tools and general hardware;
- C25.9: Manufacture of other fabricated metal products;
- C26.1: Manufacture of electronic components and boards;
- C26.8: Manufacture of magnetic and optical media;
- C27.1: Manufacture of electric motors, generators, transformers and electricity distribution and control apparatus;
- C27.2: Manufacture of batteries and accumulators;
- C27.3: Manufacture of wiring and wiring devices;
- C27.4: Manufacture of electric lighting equipment;
- C27.9: Manufacture of other electrical equipment.

Consumer Goods
- Durable Consumer Goods;
- Non-Durable Consumer Goods.

Durable Consumer Goods
- C26.4: Manufacture of consumer electronics
- C26.7: Manufacture of optical instruments and photographic equipment;
- C27.5: Manufacture of domestic appliances;

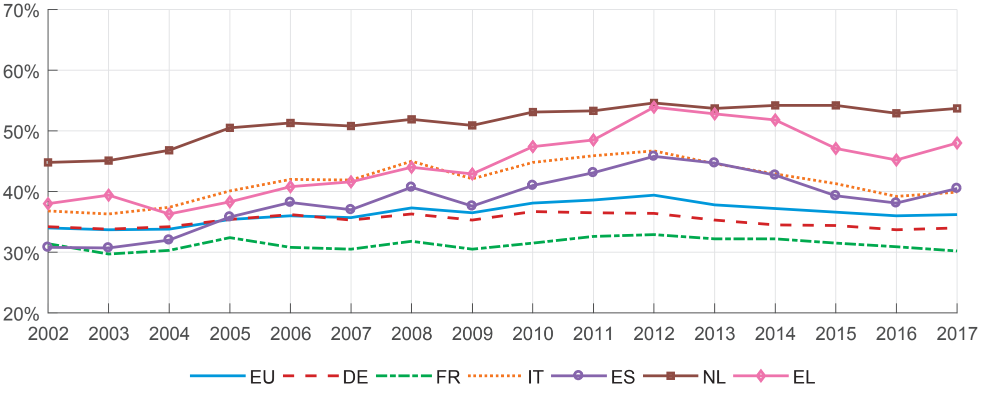
- C30.9: Manufacture of transport equipment, n.e.c.;
- C31: Manufacture of furniture;
- C32.1: Manufacture of jewellery, bijouterie and related articles;
- C32.2: Manufacture of musical instruments.

Non Durable consumer goods

- C10.1: Processing and preserving of meat and meat products;
- C10.2: Processing and preserving of fish, crustaceans and molluscs;
- C10.3: Processing and preserving of fruit and vegetables;
- C10.4: Manufacture of vegetable and animal oils and fats;
- C10.5: Manufacture of dairy products;
- C10.7: Manufacture of bakery and farinaceous products;
- C10.8: Manufacture of other food products;
- C11: Manufacture of beverages;
- C12: Manufacture of tobacco products;
- C13.9: Manufacture of other textiles;
- C14: Manufacture of wearing apparel;
- C15: Manufacture of leather and related products;
- C18: Printing and reproduction of recorded media;
- C20.4: Manufacture of soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations;
- C21: Manufacture of basic pharmaceutical products and pharmaceutical preparations;
- C32.3: Manufacture of sports goods;
- C32.4: Manufacture of games and toys;
- C32.9: Manufacturing, n.e.c.

6.2 Share of imports by country of origin and invoice currency

Figure 5: Percentage share of Extra EU28 imports to total imports



6.3 Data sources

The import prices are available in Eurostat under Database by Themes -> Industry, trade, and services -> Short term business statistics -> Industry -> Import prices in industry. The Consumer price index and industrial production were also obtained from Eurostat, while the real and nominal effective exchange rates from the international financial statistics of the IMF. For this paper the series have been downloaded through the Macrobond software and it has been seasonally adjusted using the X-13 procedure in Eviews.

6.4 ERPT estimates with Akaike information criterion

In the single equation framework of Section 2 we work with an ARDL model, where we choose the optimal model using SIC. It is well known that SIC favours more parsimonious models, while the Akaike information criterion (AIC) tends to overestimate the correct number of lags in VARs and ARDL models. Thus, the information criteria may be seen as an upper and lower bound of the true number of lags. In this section we test our results for robustness by re-estimating the ARDL models with AIC as a selection mechanism.

Table 2 summarizes the results. There are only few differences compared to Table 1 and our main conclusions hold: The ERPT is on average low; Third market effects are present and the aggregate estimate lies between the intra- and extra euro area trade. In terms of magnitude the values are highly similar overall. The most notable difference is is the aggregate estimates for Germany, which are now insignificant. The reason is that the AIC suggest a large lag for NEER, $n_e = 9$, with the majority of the lag coefficients being insignificant (β_2 through β_8), while β_9 is significant. Hence the estimated standard errors are large and lead to insignificant long-run estimate.

Table 2: Long-run exchange rate pass-through estimates.

Endogenous variable	EA	DE	FR	IT	ES	NL	EL
Composite price index							
p^{agg}	-0.17*	-0.15	-0.09	-0.21*	-0.29*	-0.38*	-0.03
p^{intra}	-0.14*	0.13	-0.13	-0.23	-0.15	-0.28*	-0.03
p^{extra}	-0.24*	-0.20	-0.14	-0.30*	-0.42	-0.46*	-0.11
Consumer goods prices							
$p^{CNS,\,agg}$	-0.22*	-0.35*	-0.25*	-0.45*	-0.68*	-0.53*	-0.12
$p^{CNS,\,intra}$	-0.13*	-0.10*	-0.08	0.04	-0.18	-0.53*	-0.04
$p^{CNS,\,extra}$	-0.24*	-0.49*	-0.40*	-0.52*	-1.27*	-0.85*	-0.17*
Intermediate goods prices							
$p^{NTR,\,agg}$	-0.18*	-0.24	0.06	-0.34*	-0.43*	-0.37*	-0.01
$p^{NTR,\,intra}$	-0.14	-0.16	0.01	-0.27	-0.12	-0.46*	0.10
$p^{NTR,\,extra}$	-0.17*	-0.37*	-0.25*	-0.72*	-1.00*	-0.56*	-0.15
Capital goods prices							
$p^{CAP,\,agg}$	-0.14*	-0.32*	-0.14*	-0.17	-0.25	-0.60*	-0.01
$p^{CAP,\,intra}$	-0.04	-0.06*	-0.06*	-0.03	-0.01	-0.39*	0.01
$p^{CAP,\,extra}$	-0.26*	-0.41*	-0.23*	-0.54*	-0.82*	-0.72*	-0.07

Estimates of long-run ERPT using the Akaike information criterion for model selection. A star (*) indicates significance at the 5% level.

6.5 Long-run ERPT estimates from a selection of studies

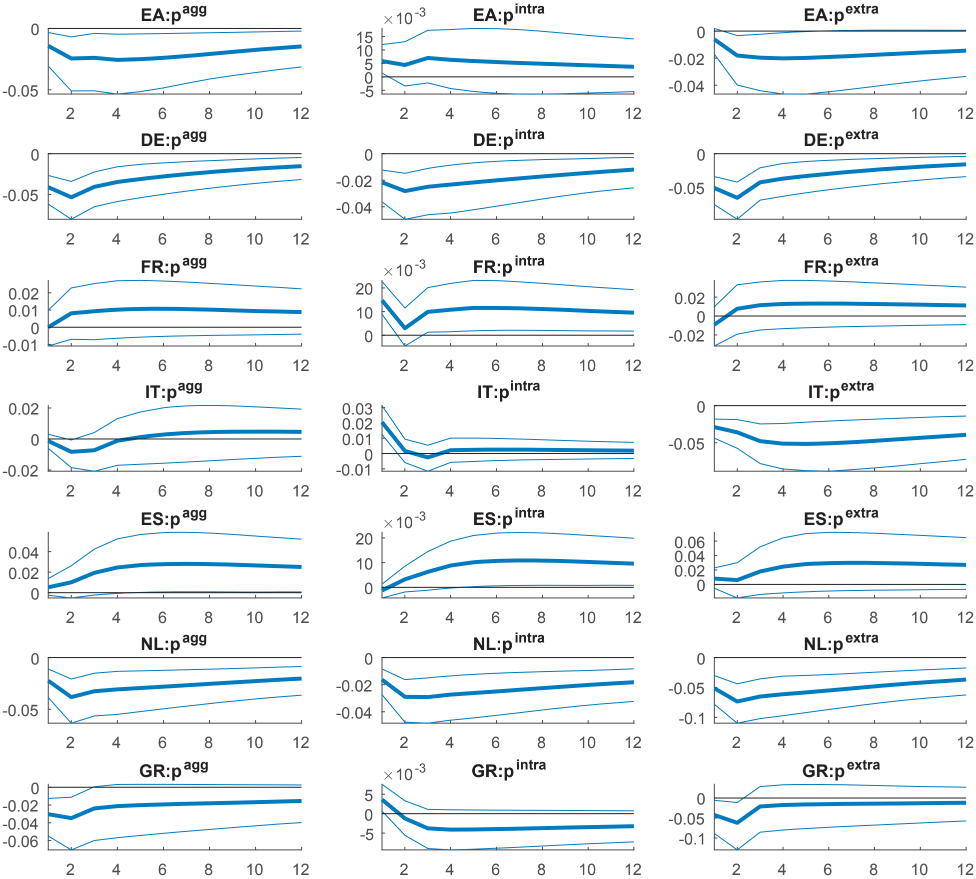
Table 3: Sample of long-run exchange rate pass-through estimates.

Research Article	Sample	Dep.	DE	FR	IT	ES	NL	GR
Devereux and Yetman (2002)	1970–2001	CPI	0.05	0.10	0.17	0.20	0.05	0.39
Gagnon and Ihrig (2004)	1971–2003	CPI	0.11	0.23	0.36	0.19	0.16	0.52
Gagnon and Ihrig (2004)*	1985–2003	CPI	0.12	0.01	0.08	0.03	0.06	0.27
Warmedinger (2004)	1980–1999	P^{IMP}	0.44	0.16	0.26	0.18		
Campa and Goldberg (2005)	1975–2003	P^{IMP}	0.80	0.98	0.35	0.70	0.84	
de Bandt et al. (2008)**	1995–2004	UVI	0.78	0.70	0.67	0.75	0.73	0.65
Bussiere (2013)	1980–2006	P^{IMP}	0.33	0.77	0.72			
de Bandt and Razafindrabe (2014)	2007–2013	P^{IMP}_{new}	0.73			1.43	0.63	0.42
Choudhri and Hakura (2015)	1979–2010	P^{IMP}	1.08	1.20	0.88	1.19	1.83	
Gopinath (2015)	1999–2014	CPI	0.24	0.04	0.13	0.08		
Özyurt (2016)***	1999–2015	P^{IMP}_{nea}	0.44	0.61	1.16	0.75	0.55	
Turner and Wood (2017)	1979–2015	P^{IMP}	0.65	0.20	0.72	0.87	0.86	

Comparison of different exchange rate pass-through estimates. Changes to the price level, as proxied by different dependent variables (Dep.), in response to a one percent depreciation of the exchange rate. CPI denotes the consumer price index; P^{IMP} is the import price index as defined in the OECD database; UVI denotes unit value index; P^{IMP}_{new} denotes the new Eurostat dataset on import prces; P^{IMP}_{nea} is the import price deflator of non-euro area goods and services; The countries are given by 2-digit ISO code. *The beginning year of the subsample ranges from 1981 for Germany until 1994 for Greece; **Pass-through estimated at SITC level, values are averages; ***Reported the estimates for one year ahead.

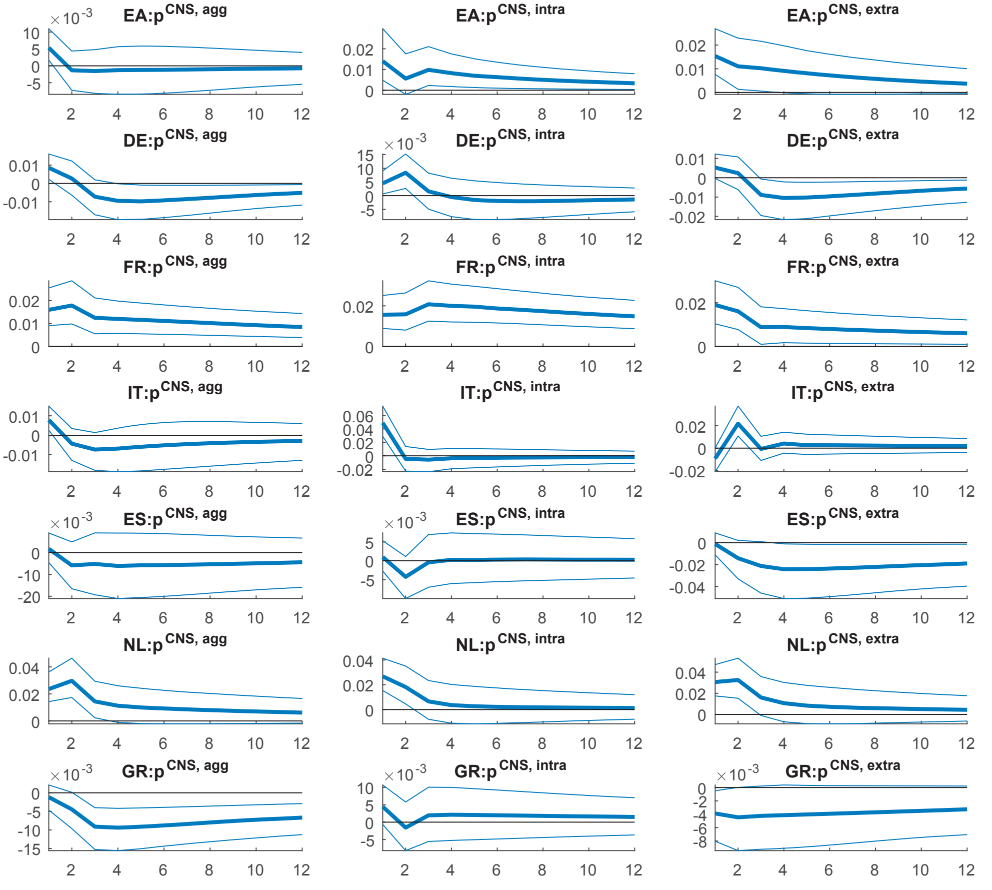
6.6 Exchange rate uncertainty IRFs of import prices

Figure 6: Composite import price index following a volatility shock in the exchange rate.



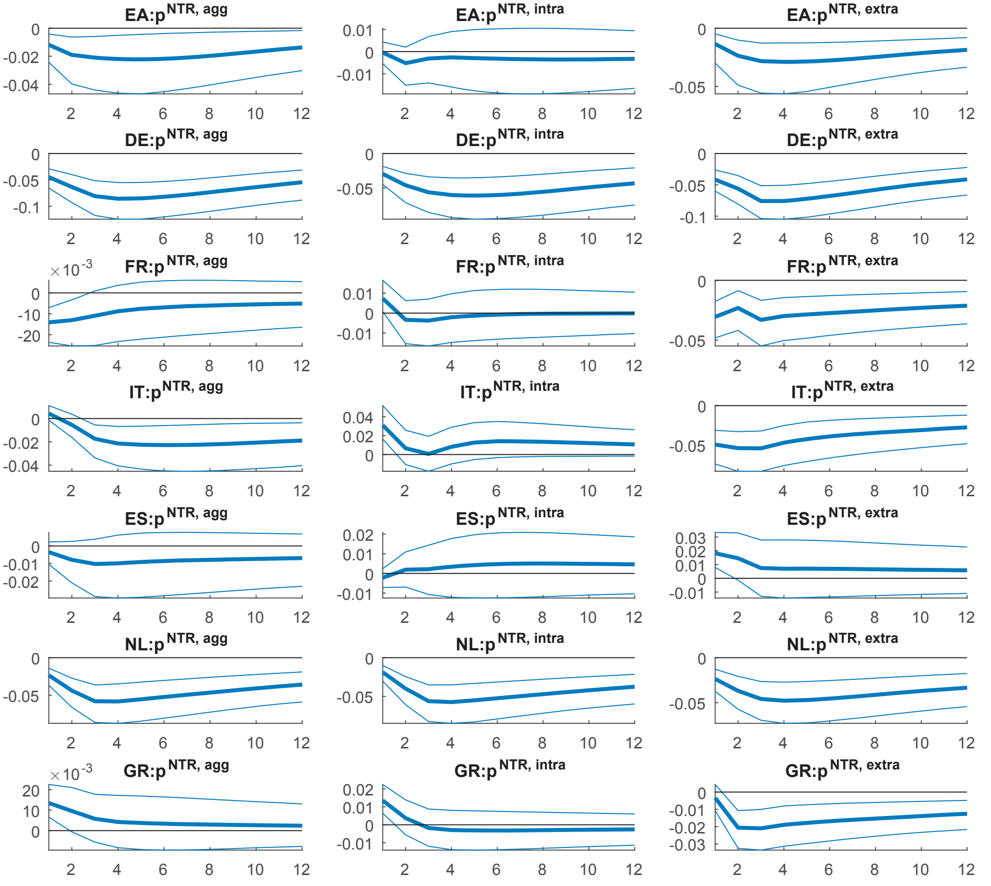
Impulse responses of the composite import price index (CMP) and one standard deviation (s.d.) probability intervals following a shock to the volatility of exchange rate shocks from a VAR a lá Mumtaz and Zanetti (2013). Countries denoted by the 2-digit ISO code. Aggregate prices, prices of euro area imports (intra), and non-euro area imports (extra).

Figure 7: Consumption goods' import price index following a volatility shock in the exchange rate.



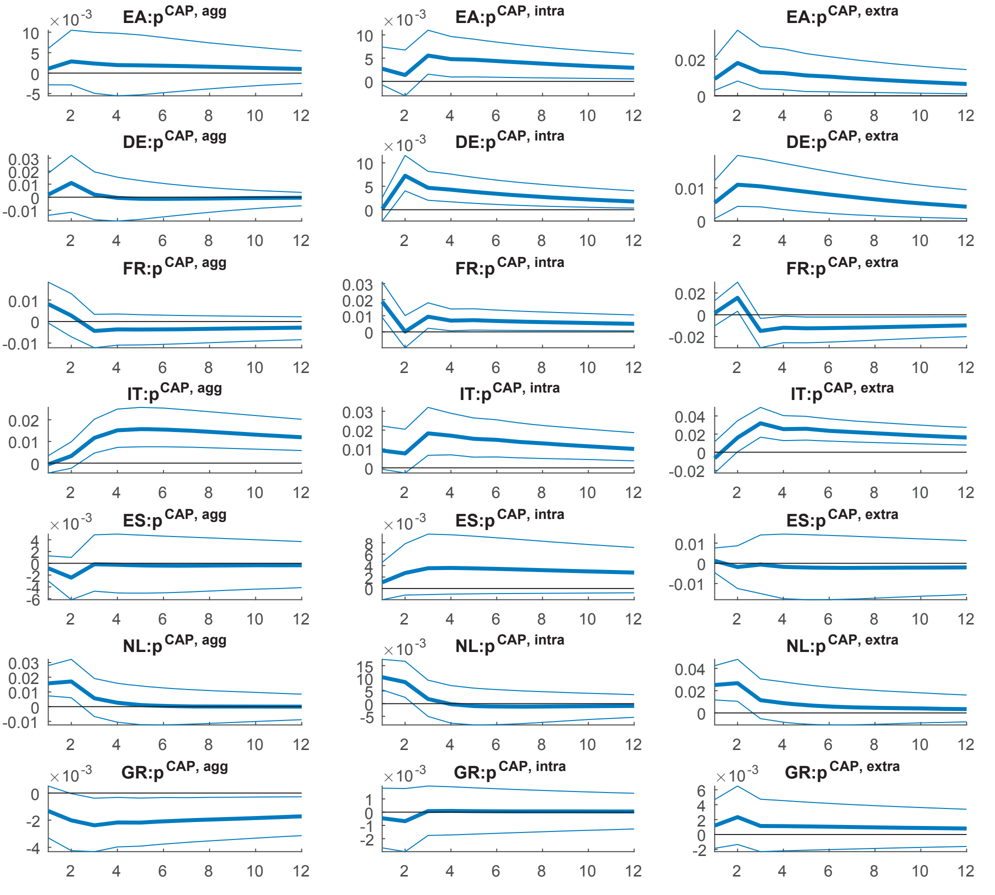
Impulse responses of the consumption goods' import price index (CNS) and one standard deviation (s.d.) probability intervals following a shock to the volatility of exchange rate shocks from a VAR a lá Mumtaz and Zanetti (2013). Countries denoted by the 2-digit ISO code. Aggregate prices, prices of euro area imports (intra), and non-euro area imports (extra).

Figure 8: Intermediate goods' import price index following a volatility shock in the exchange rate.



Impulse responses of the intermediate import price index (CMP) and one standard deviation (s.d.) probability intervals following a shock to the volatility of exchange rate shocks from a VAR a lá Mumtaz and Zanetti (2013). Countries denoted by the 2-digit ISO code. Aggregate prices, prices of euro area imports (intra), and non-euro area imports (extra).

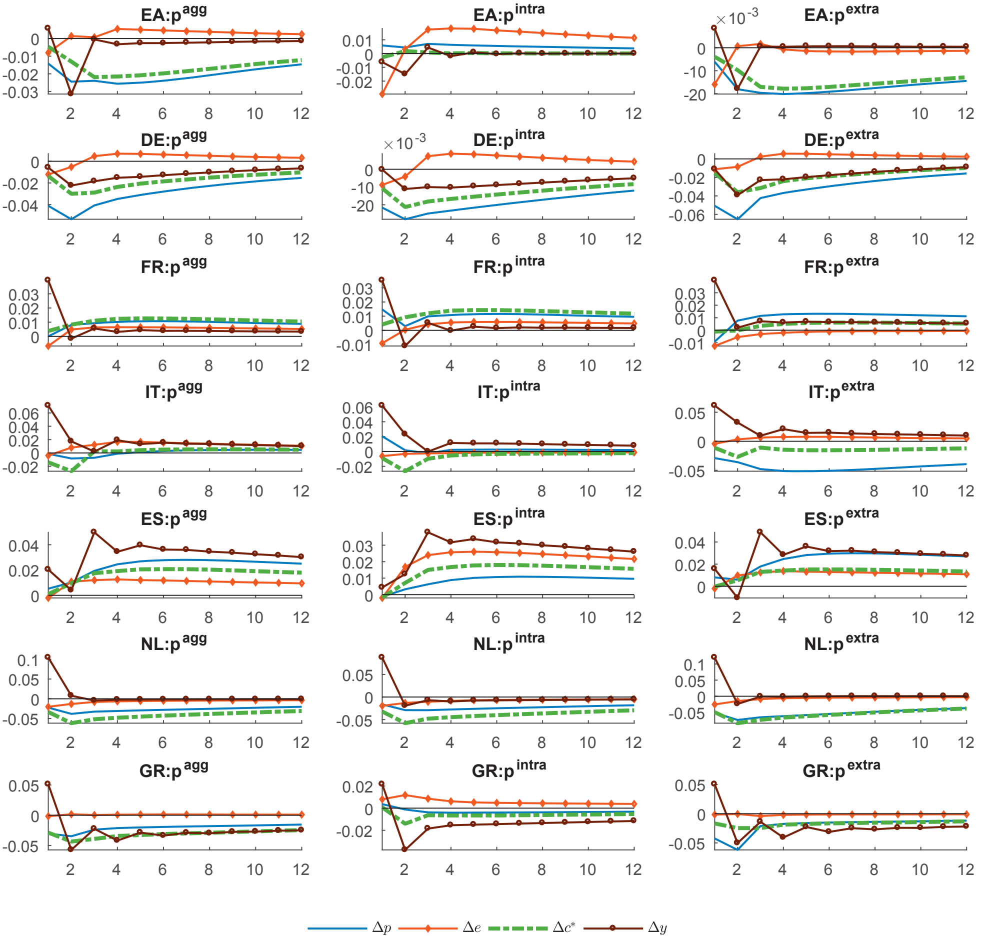
Figure 9: Capital goods' import price index following a volatility shock in the exchange rate.



Impulse responses of the capital import price index (CMP) and one standard deviation (s.d.) probability intervals following a shock to the volatility of exchange rate shocks from a VAR a lá Mumtaz and Zanetti (2013). Countries denoted by the 2-digit ISO code. Aggregate prices, prices of euro area imports (intra), and non-euro area imports (extra).

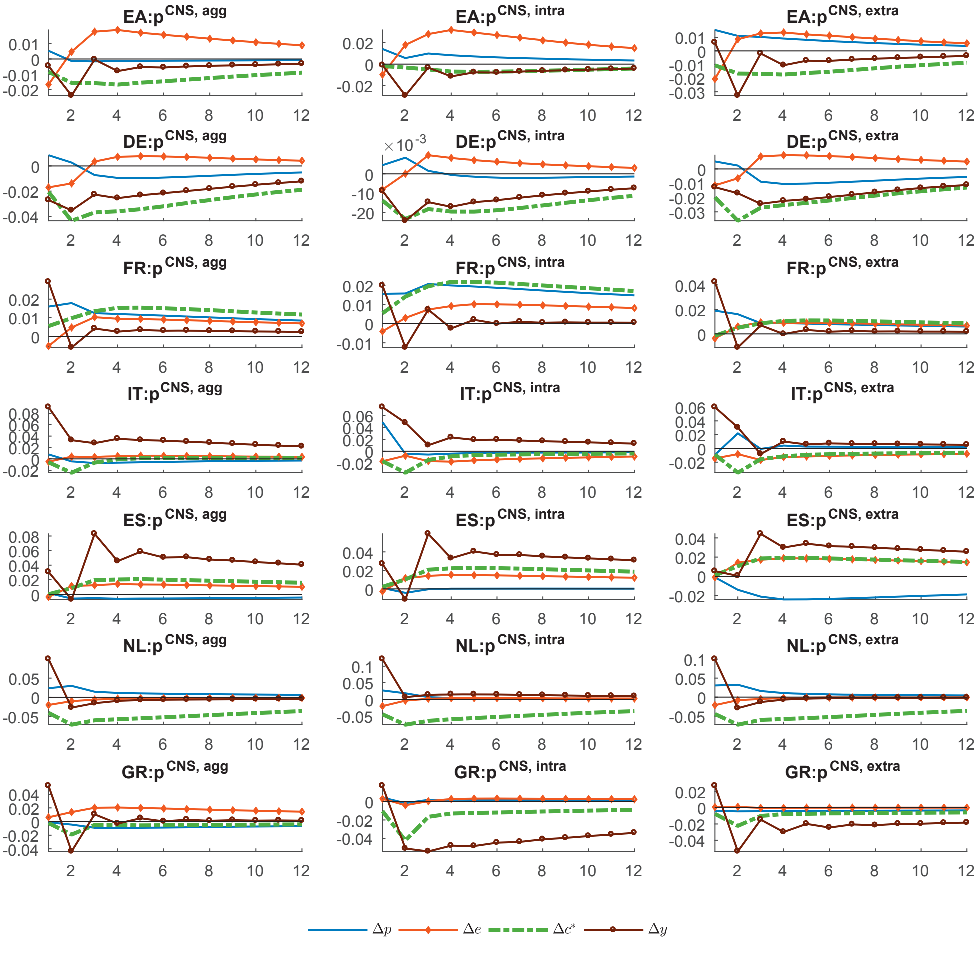
6.7 Exchange rate uncertainty full IRFs

Figure 10: Composite import price index following a volatility shock in the exchange rate.



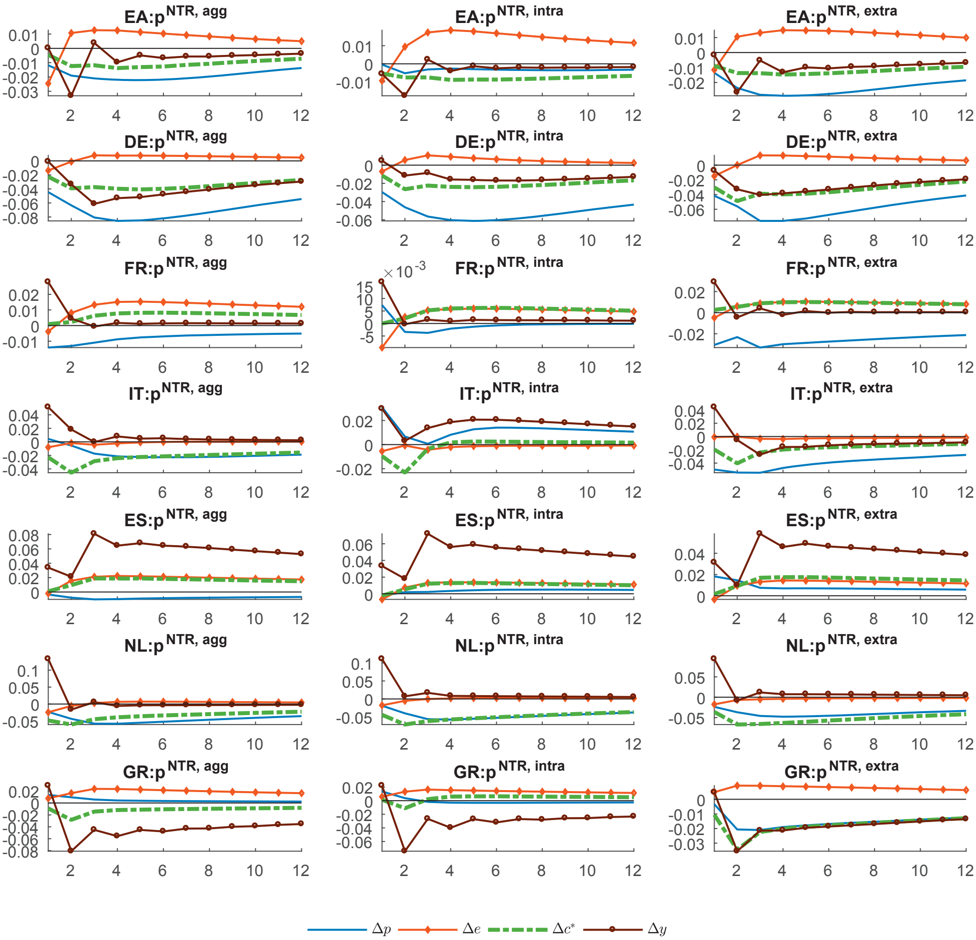
Impulse responses of the composite import price index (CMP), p, nominal effective exchange rate, e, producer's cost proxy, c^* and industrial production, y, following a shock to the volatility of exchange rate shocks from a VAR a lá Mumtaz and Zanetti (2013). One standard deviation probability intervals for the import prices. Countries denoted 2-digit ISO code. Aggregate prices, prices of euro area imports (intra), and non-euro area imports (extra).

Figure 11: Consumption goods' import price index following a volatility shock in the exchange rate.



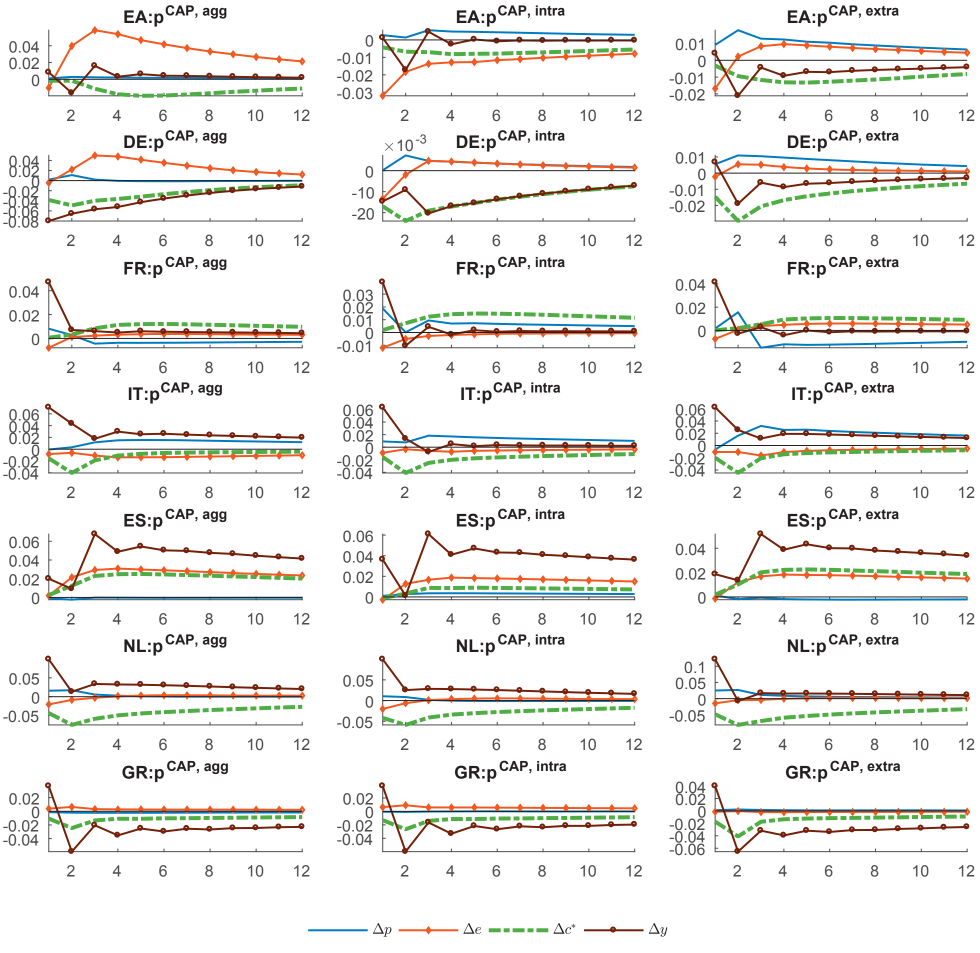
Impulse responses of the composite import price index (CON), p, nominal effective exchange rate, e, producer's cost proxy, c^* and industrial production, y, following a shock to the volatility of exchange rate shocks from a VAR a lá Mumtaz and Zanetti (2013). One standard deviation probability intervals for the import prices. Countries denoted 2-digit ISO code. Aggregate prices, prices of euro area imports (intra), and non-euro area imports (extra).

Figure 12: Intermediate goods' import price index following a volatility shock in the exchange rate.



Impulse responses of the composite import price index (INT), p, nominal effective exchange rate, e, producer's cost proxy, c^* and industrial production, y, following a shock to the volatility of exchange rate shocks from a VAR a lá Mumtaz and Zanetti (2013). One standard deviation probability intervals for the import prices. Countries denoted 2-digit ISO code. Aggregate prices, prices of euro area imports (intra), and non-euro area imports (extra).

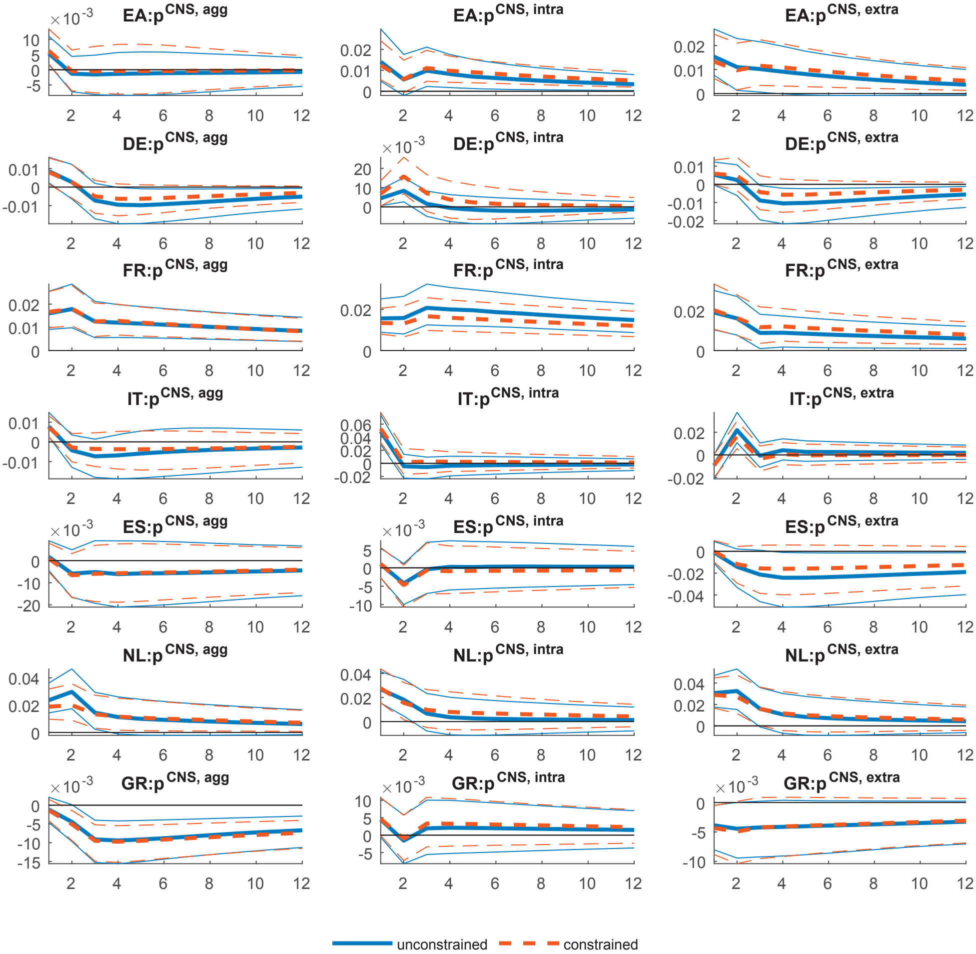
Figure 13: Capital goods' import price index following a volatility shock in the exchange rate.



Impulse responses of the composite import price index (CAP), p, nominal effective exchange rate, e, producer's cost proxy, c^* and industrial production, y, following a shock to the volatility of exchange rate shocks from a VAR a lá Mumtaz and Zanetti (2013). One standard deviation probability intervals for the import prices. Countries denoted 2-digit ISO code. Aggregate prices, prices of euro area imports (intra), and non-euro area imports (extra).

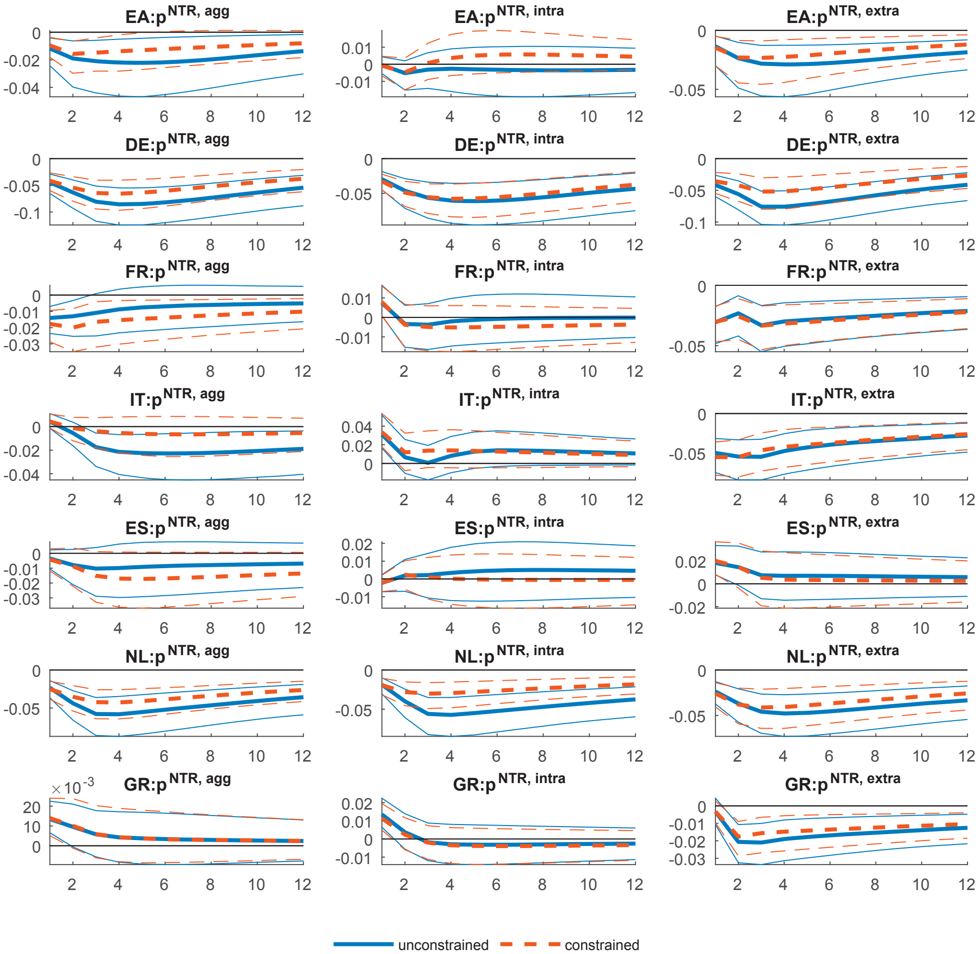
6.8 Constrained vs. unconstrained models' IRF

Figure 14: Impulse response functions: Constrained vs. unconstrained model



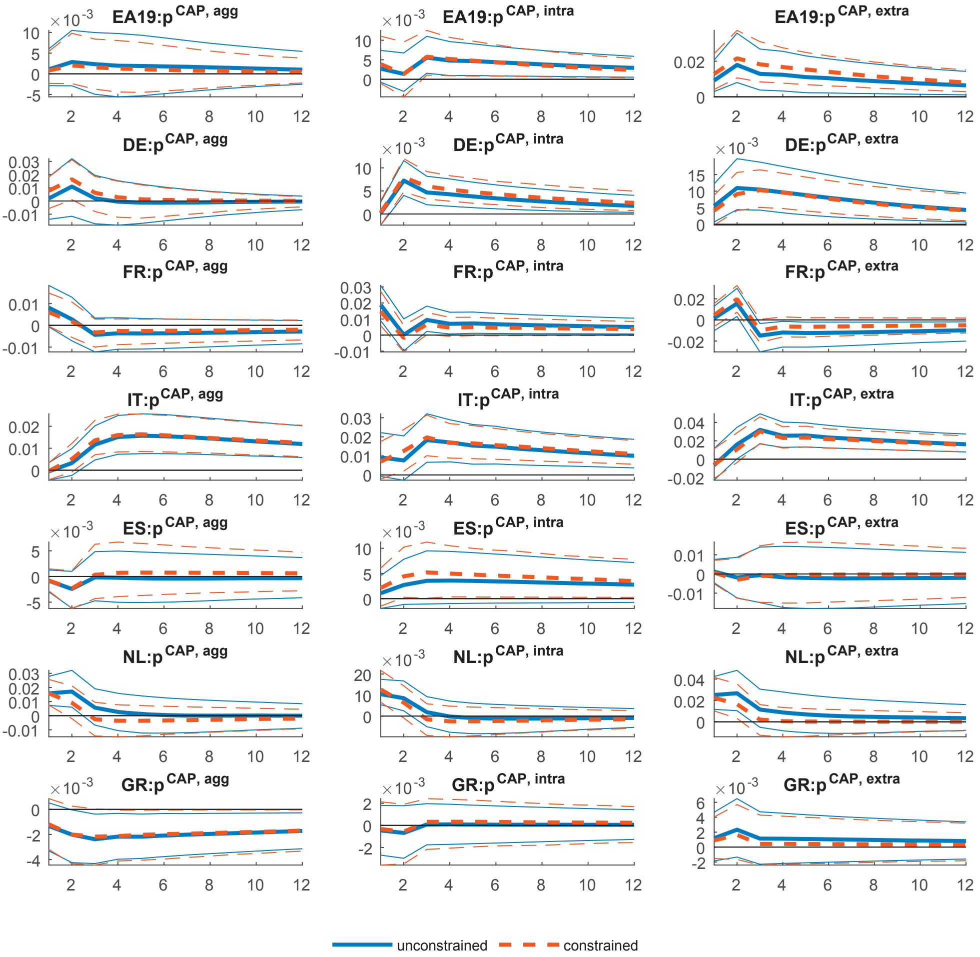
Response of the consumption goods' import price index for aggregate, euro area and non-euro are imports following a change to the volatility of the exchange rate shocks. Unconstrained model as laid out in the previous section, constrained model presents the response to prices following the volatility change all else held equal.

Figure 15: Impulse response functions: Constrained vs. unconstrained model



Response of the intermediate goods' import price index for aggregate, euro area and non-euro are imports following a change to the volatility of the exchange rate shocks. Unconstrained model as laid out in the previous section, constrained model presents the response to prices following the volatility change all else held equal.

Figure 16: Impulse response functions: Constrained vs. unconstrained model



Response of the capital goods' import price index for aggregate, euro area and non-euro are imports following a change to the volatility of the exchange rate shocks. Unconstrained model as laid out in the previous section, constrained model presents the response to prices following the volatility change all else held equal.