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Exchange rate uncertainty and import prices in the euro area

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Abstract

This paper analyzes the effects of exchange rate uncertainty on the pricing behavior of import firms in the euro area. Uncertainty is measured via the volatility of the structural shocks to the exchange rate in a nonlinear vector-autoregressive model 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. Controlling for the origin of imports (within or outside the euro area) is important for assessing the impact of exchange rate movements on prices.

JEL CLASSIFICATION

C11; C22; F31

1 | INTRODUCTION

Does an increase in exchange rate uncertainty influence import prices? How do export and import firms react when faced with elevated levels of exchange rate fluctuations? Since abandoning the gold standard, exchange rates have exhibited high volatility while most macroeconomic aggregates have remained stable (Baxter & Stockman, 1989; Corsetti, Dedola, & Leduc, 2008; Obstfeld & Rogoff, 2000). In addition, it has been shown that the pass-through from changes in the level of the exchange rate to import prices (ERPT) for many advanced economies is low.¹

From the viewpoint of international trade theory, however, exchange rate uncertainty does influence the pricing behavior of firms. The relationship is yet complex and the reaction of import prices depends ultimately on which party bears the exchange rate risk. In the literature on exchange rate uncertainty and international trade flows, for example, exchange rate risk arises as a product of the leads in contracts

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and lags in payments in international trade (Canzoneri, 1984; Clark, 1973; Froot & Klemperer, 1989; Gagnon, 1993; Hooper & Kohlhagen, 1978). If the contracts are stipulated in the exporters' currency, it is then the importers who bear the exchange rate risk. In this case, higher uncertainty results in lower import demand, which ultimately drives prices downwards. In contrast, if the exporters bear the exchange rate risk, it gets priced in as means of hedging and therefore prices rise. In the literature on ERPT for example, exchange rate risk arises from the difference in the way that products are sold in the importing market (Devereux & Engel, 2002). Producers might choose to sell their products directly or go through a distributor. In the former case, exporters bear the exchange rate risk, while in the latter it is carried by the distributors/importers, who buy products in a foreign currency and sell it at the domestic market. Thus, again it is important which party bears the risk, even if it is for different reasons.

Given this ambiguity it is natural to turn to empirical studies to examine which case gains more support from the data. However, the empirical literature on exchange rate uncertainty and trade has been inconclusive as well and, for the most part, it has focused on the effects on trade flows (i.e., quantities) with only limited attention paid to prices. For example, Cushman (1983) analyzes the bilateral trade flows between the United States and Germany, France, Canada, and Japan and reports negligible effects of exchange rate risk on prices. Kroner and Lastrapes (1993) use a similar country dataset and report statistically significant impact on prices only for Japan and the United Kingdom. Anderton and Skudelny (2001) set up a panel for the euro area member states and find in most cases insignificant effects of exchange rate uncertainty on prices. Meanwhile, more recent studies on ERPT have advocated the importance of the link between exchange rate volatility and import prices. For example, Campa and Goldberg (2005), Corsetti et al. (2008), Frankel, Parsley, and Wei (2012), and Ozkan and Erden (2015) show that the exchange rate volatility is an important determinant of the ERPT and hence should be considered in pass-through models to alleviate potential bias in ERPT estimates.

Given the inconclusive theoretical and empirical evidence of exchange rate uncertainty as a driver of import prices and the potential importance for policy makers, in this paper we set out to investigate the relationship empirically. Our starting point is a setup from the ERPT literature, which we augment along several dimensions. First, we use a structural vector-autoregressive model (SVAR) with stochastic volatility to identify the exchange rate shocks, whose conditional volatility we interpret as a measure of exchange rate uncertainty.² The stochastic volatility component is then introduced as an additional exogenous regressor in the VAR, making the level of the endogenous variables a function of the second moments. This allows us to estimate how import prices react following an increase in the exchange rate uncertainty.³

While this paper is primarily focused on the effects of exchange rate uncertainty on import prices, it contributes to the ERPT literature as well through its use of a novel dataset on import prices for the euro area and some of its largest economies.⁴ The main advantage of these data is that the price index is available for intra- and extra-euro area trade separately. This may help alleviate potential bias when it comes to ERPT estimates since a significant proportion (on average 40%) of euro area trade takes place between the member states. Controlling for the origin of trade was previously possible only when using unit value indices instead of import prices, which, however, reflect not only quantity, but also quality changes of the goods.⁵ A further advantage of our dataset is the availability of additional subcomponents of the price index. It has been highlighted in the literature that the relationship between the exchange rate dynamics and import prices is heterogeneous across industries (De Bandt, Banerjee, & Kozluk, 2008). We can therefore use these new data to gain further insight into the interplay between import prices and exchange rates.

Our findings contribute to the literature in three ways. First, 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 primarily driven by a decrease

in the prices of intermediate goods. On the contrary, consumer and capital goods' prices either rise or are unresponsive. Moreover, significant effects from exchange rate volatility are observed even in cases where the ERPT is extremely low or insignificant. Second, we find that the effects on import prices from extra-euro area trade are more pronounced than those from intra-euro area trade. These findings show that a bias in ERPT estimates would arise when the aggregate import price index is used. Third, the country specific analysis highlights the prevalent notion in the literature of a large degree of pricing behavior heterogeneity across countries. Furthermore, the effects of uncertainty vary across product groups and origin of imports. These results suggest that even in the presence of low ERPT exchange rate fluctuations are a source of inflation.

The remainder of this article is structured as follows. In the next section, we present our dataset to highlight the gains from using disaggregation by origin of imports. In Section 3 we lay down the econometric framework for the extraction of our measure of exchange rate uncertainty and present 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

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

We use an industrial import price index dataset from Eurostat's short-term business statistics. The series start in 2005 for most countries and are available at a monthly frequency. The countries covered are the euro area 19 aggregate, Germany, France, Italy, Spain, Netherlands, Greece, Slovakia, and Lithuania.⁶ 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). They are recorded at the transfer of ownership, and are expressed per unit of goods.⁷

The dataset tracks price development of an array of goods in multiple industries based on the Classification of Products by Activity (CPA)/NACE Rev.2 classes B, C, and D. These products are then grouped together in end-use categories that constitute the Main Industrial Groupings (MIG) and further aggregated to a composite index.⁸ In this study we analyze the following indices: composite import price index (CMP), consumer goods (CNS), capital goods (CAP), and intermediate goods (NTR) and omit the energy index, mainly because of 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 two-thirds of the trade volume within the European union (EU28). 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 $\Delta e_t^{intra} = 0$, 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, that is,

$p_t^{agg} = \lambda_t p_t^{intra} + (1 - \lambda_t) p_t^{extra}$ 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). Hypothetically, a rising λ_t could even lead to the conclusion that the ERPT is time-varying when it was in fact the composition of imports that has shifted.⁹ Since in our dataset those series are available, we use them to provide further insight into the interplay between intra- and extra-euro area trade prices and the exchange rate dynamics.

2.1 | Choosing the main determinants of import prices

Controlling for the main determinants of import prices is of utmost importance to study the effects of exchange rate uncertainty effectively, as to reduce a potential omitted variable bias. 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 & Goldberg, 2005).

$$\Delta p_t = \alpha + \sum_{i=0}^{n_e} \beta_i \Delta e_{t-i} + \sum_{i=0}^{n_y} \gamma_i \Delta y_{t-i} + \sum_{i=0}^{n_c} \delta_i \Delta c_{t-i}^* + \sum_{j=1}^{n_p} \zeta_j \Delta p_{t-j} + \epsilon_t. \quad (4)$$

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, $\epsilon_t \sim N(0, \sigma^2)$.

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 regarding what proxy is best. One approach is to use foreign unit labor costs (ULC) (Bailliu & Fujii, 2004). The economic argument here is that producers choose a destination specific mark-up and thus 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 (known as "pricing-to-market" or PTM—see e.g., Goldberg & Knetter, 1997; Marston, 1990). 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 single European 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 partly accounted for using lagged prices and can explain why our findings remained similar.¹⁰ Another potential pitfall of the ULC specification is that ULC are available on quarterly frequency, thus interpolation was needed to construct c^* .

To create 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 $c^* = cpi^*$.

2.2 | Revisiting the ERPT in the euro area

To give some context of the import price dataset and compare it with other studies we do a reduced-form analysis of the ERPT. We estimate Equation 4 per country for each combination of import price index and origin of products, that is, $p^{j,k}$ for $j \in \{CMP, CNS, NTR, CAP\}$ and $k \in \{agg, intra, extra\}$. The data ranges from January 2005 to September 2018.¹¹

Equation 4 is an autoregressive distributed lag model of order n_x , $x \in \{e, c, p, y\}$. The estimate for short-run ERPT is defined as $\hat{\beta}_0$ and the long-run pass-through (LR-ERPT) estimate by $\sum_i \hat{\beta}_i / \left(1 - \sum_j \hat{\xi}_j \right)$.

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 similar estimates both qualitatively and quantitatively (reported in Table A3 the Appendix).

Table 1 shows the point estimates of LR-ERPT following a 1 percentage-point appreciation of the nominal exchange rate.¹² Starting from the composite index, the long-run pass-through is significantly different from zero for the euro area as a whole, Germany, Italy, Spain, and the Netherlands (and insignificant in France and Greece). In all countries it is incomplete and rather low, thus we can reject the notion of producer currency pricing. Compared with the other studies estimated pass-through is lower (in absolute values) and in two countries insignificant.¹³ On average the aggregate index for intermediate goods seems to have the highest pass-through, while capital goods are far less susceptible to exchange rate changes.

The disaggregation by origin of products provides insight into the import price dynamics. There is evidence for third market effects, seen in the significant responses of intra-euro area goods' prices to changes in the NEER.¹⁴ 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 are always between the intra- and extra-euro area trade estimates, that is, 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.

TABLE 1 Long-run exchange rate pass-through estimates

Endogenous variable	EA	DE	FR	IT	ES	NL	GR
<i>Composite price index</i>							
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
<i>Consumer good prices</i>							
$p^{CNS,agg}$	−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*
<i>Intermediate goods prices</i>							
$p^{NTR,agg}$	−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
<i>Capital good prices</i>							
$p^{CAP,agg}$	−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*

Note: Estimates of long-run ERPT, changes to import prices following a 1% appreciation of the nominal exchange rate. In percentage points. 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 two-digit ISO code, are euro area 19 (EA), Germany (DE), France (FR), Italy (IT), Spain (ES), the Netherlands (NL), and Greece (GR). An asterisk (*) indicates significance at the 5% level.

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 with the findings of De Bandt et al. (2008), who show similar results with UVI 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. Intermediate industrial goods are the most susceptible to exchange rate fluctuations. Compared with 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.

3 | EXCHANGE RATE UNCERTAINTY AND IMPORT PRICES

Having laid out the foundation of modeling the import prices we now turn to analyzing the effects of exchange rate uncertainty. We suggest an uncertainty measure based on a SVAR with stochastic volatility to the structural shocks. The adopted measure is the conditional variance of the exchange rate series from the structural model.¹⁵ We incorporate the stochastic volatility as an exogenous variable in the VAR by allowing the levels of the variables, for example, the import prices, to react to changes in the volatility.

The framework has been proposed by Mumtaz and Zanetti (2013) for the study of monetary policy uncertainty on economic activity. It differs from other methods of assessing the effects of uncertainty along several dimensions. First, it is a one-step procedure.¹⁶ In contrast to other methods, where the uncertainty index is constructed first and then put into a model, we estimate both the uncertainty index and the model parameters jointly. Corsetti et al. (2008) and Ozkan and Erden (2015) have shown that this is important in ERPT context, the coefficients in ERPT models are functions of the exchange rate volatility. Moreover, this method of extracting uncertainty is predominantly data driven and alleviates the need to take many assumptions on the researchers' part. For example, extracting conditional volatility from spot rates vs. futures contracts requires additional assumptions such as the choice of contract duration and type of contract, on top of the usual choices about the model, such as the lag length of the GARCH specification used to extract the conditional volatility.¹⁷

Furthermore, by using a structurally identified VAR we aim to address a potential pitfall of the reduced-form framework in that our shocks have clear economic interpretation. By introducing stochastic volatility to the structural shocks as opposed to the residuals we are able to model exchange rate uncertainty as it is typically defined in theoretical models (the standard deviation of shocks), whereas the volatility of the residuals is a linear combination of multiple economic innovations.¹⁸

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

$$Z_t = c + \sum_{i=1}^n \beta_i Z_{t-i} + \sum_{j=0}^{n_{ex}} \gamma_j \tilde{h}_{t-j} + \Psi_t^{0.5} u_t \quad (5)$$

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 $\tilde{h}_t = [h_{1t}, \dots, h_{Nt}]$ 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).

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

Introducing the stochastic volatilities as additional variables in Equation 5 allows for analyzing the effects of second-order moments on the levels. The volatility and the parameters are estimated jointly, hence we do not have to rely on two-step estimations with proxies—the uncertainty is considered when estimating the model relationships. Furthermore, \tilde{h}_t 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, for example, 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.

Owing to the presence of the volatility terms in Equation 5 the conventional maximum likelihood approach is not applicable. The model is estimated via Bayesian methods with Gibbs sampling, that is, 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 $\tilde{H} = [H_1, \dots, H_T]$ 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 $\Omega = [A, B, Q, \tilde{H}, \Theta]$ collects all the parameter blocks and the superscript $-i$ denotes the exclusion of the i th block such that $\Omega^{-B} = [A, Q, \tilde{H}, \Theta]$.

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:

- Conditional on \tilde{H} , A may be drawn as a linear regression from $p(A|\Omega^{-A})$, given the form in Equation 6 in conjunction with the algorithm of Cogley and Sargent (2005).
- 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 $t = 1, \dots, T$ to get the estimates based on the full sample $\beta_{T|T}$ and $\gamma_{T|T}$ and draw the parameters from $p(\beta_{T|T}, \gamma_{T|T} | Q, \Omega^{-B-Q})$.
- Conditioning on the draws for B , Q may be drawn from an inverse Wishart distribution.
- Given the reduced-form coefficients, the stochastic volatility estimation follows Cogley and Sargent (2005), where the draws for \tilde{H} may be obtained using a Metropolis–Hastings algorithm.

We estimate the model with the variables in Equation 4. The priors are initialized using a training sample of 35 observations (similar to Primiceri (2005) and Mumtaz and Zanetti (2013)) or roughly 3 years at monthly frequency. The prior for the reduced-form coefficients is based on 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 so for simplicity given the already nonlinear 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 Equation 4, however, our results prove robust to the permutation of those variables. The foreign producer cost proxy and domestic demand are positioned first, that is, they do not react contemporaneously to prices or exchange rates.¹⁹ 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 Equation 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 $n_{ex} \in [0, \dots, 4]$ (note that index j in Equation 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 the null hypothesis of no autocorrelation. In all cases this is at $n_{ex} = 1$.

While the proposed model is nonlinear, we do acknowledge that it captures only one specific nonlinearity, namely the effects of second moments of the exchange rate on import prices. There are, however, other sources of nonlinearities that we do not implement such as asymmetric effects and time-variation.

The reduced-form ERPT literature has recognized that the pass-through could be asymmetric with respect to depreciation and appreciation of the exchange rate (Brun-Aguerre & Fuertes, 2012; Delatte & López-Villavicencio, 2012). Whether this could also be true for the second moments, that is, that firms react differently to exchange rate volatility stemming from appreciation than from depreciation pressure is not captured by our nonlinear framework. The γ coefficients in Equation 5 capture the

average effect of exchange rate uncertainty on import prices. Our sample is sufficiently long such that the euro has experienced both types of pressures. The effects of exchange rate uncertainty around prolonged depreciation periods, such as during the European sovereign debt crisis, might be different from the effects in times of prolonged appreciation, for example, before the global financial crisis. The employed framework cannot incorporate asymmetric shocks and this question is left for future research.

Similarly, an additional source of nonlinearity in the ERPT literature is time variation of the pass-through (Cheikh & Rault, 2016; De Bandt & Razafindrabe, 2014; Donayre & Panovska, 2016; Nogueira & León-Ledesma, 2011), which could also be transferable to the exchange rate uncertainty. The notion that uncertainty might have different effects in different periods is gaining popularity in the macro uncertainty literature (see, e.g., Castelnuovo & Pellegrino, 2018; Pellegrino, 2017).

3.2 | Empirical estimates of the exchange rate uncertainty

We present our uncertainty measure in Figure 1. It depicts the estimated stochastic volatility of the exchange rate shocks for the countries in our sample.²⁰ The series have a similar shape, as the NEERs of the Euro for each member differ primarily as a result of different country trade-weights. 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 to 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.

We can compare our uncertainty index to existing measures in the literature. For example, building on Marston (1990) and Baum, Caglayan, and Ozkan (2004), Brun-Aguerre and Fuertes (2012) (henceforth BF) extract a measure of uncertainty from the realized volatility of the exchange rate by taking the square root of the cumulated squared logarithmic daily NEER returns. The authors employ a 1-year moving-average filter to smooth out the noise. We recreate the BF index with the NEER data for the euro area as well as a version of the index without the moving-average filter. The three indices are plotted in Figure 2 and have been standardized to facilitate comparison (therefore the negative values). They do not differ drastically from one another, which is reassuring—two different approaches yield similar shapes of the volatility. However, the index without the filter is indeed quite noisy. For example, during the 2015 to 2016 period of U.S. dollar appreciation the NEER was twice as high as the ERU index and close to the peak during the global financial crisis. On the contrary the 1-year moving average by construction is lagging—it either underestimates or overestimates the level of volatility. After

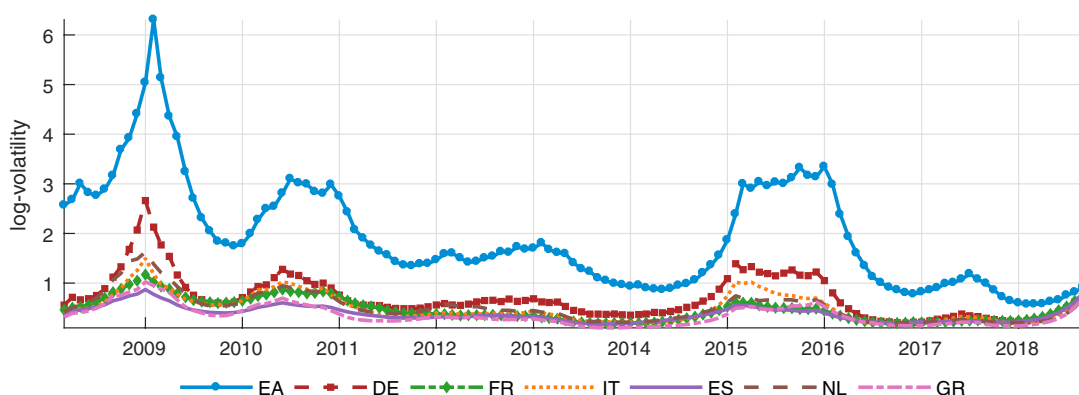


FIGURE 1 Country estimates of exchange rate uncertainty [Colour figure can be viewed at wileyonlinelibrary.com]

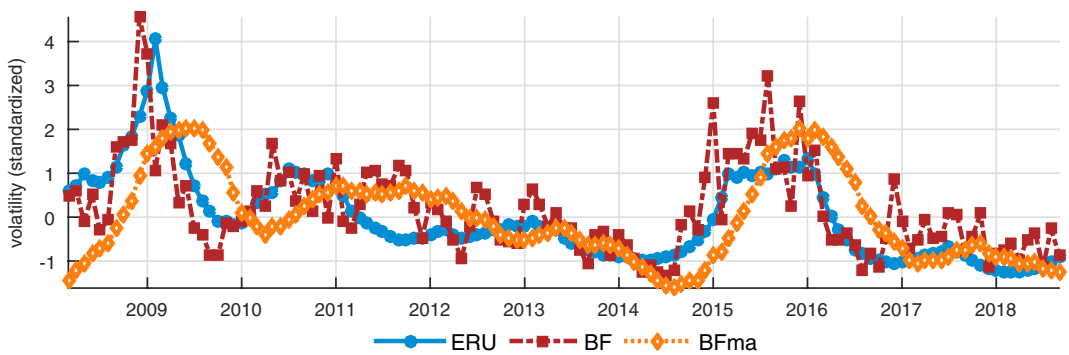


FIGURE 2 Comparison with the index of Brun-Aguerre and Fuertes (2012). *Note:* ERU: Exchange rate uncertainty index from an SVAR with stochastic volatility-in-mean. BF: Exchange rate volatility index derived from the square root of the cumulated squared logarithmic daily NEER returns. BFma: The BF index with a 1-year moving-average filter, replicating Brun-Aguerre and Fuertes (2012) [Colour figure can be viewed at wileyonlinelibrary.com]

the smoothing the 2015 to 2016 depreciation appears more turbulent than the global financial crisis. The volatility index derived from our model appears to combine the best features of both versions—it is timely, as the version without the moving-average filter, and also does not exhibit erratic behavior.

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. In contrast, normalizing the shocks is not economically meaningful, given that they represent changes to log-volatility series.²¹ 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 3 depicts the estimates with probability intervals for the composite price index.

Not conditioning on the origin of imports we find that on average prices fall in the euro area, Germany, the Netherlands and Greece, and they do not react to exchange rate uncertainty in France and Italy. In Spain we find marginally significant inflation in imports. Disaggregating the effects by import origin 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 the prices of minor third market effects. However, the general direction of the point estimates is different compared with 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 4 plots the CNS, NTR, and CAP indices, along with the composite index from Figure 3.²² 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 show a heterogeneous impact between intra- and extra-euro

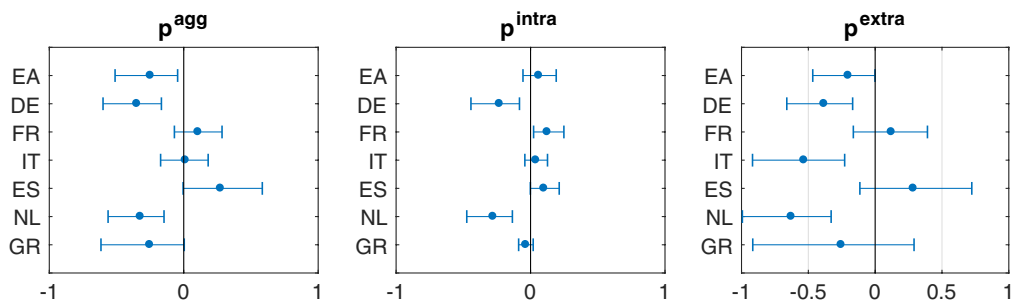


FIGURE 3 Response of the composite import price index after an exchange uncertainty shock. *Note:* Cumulative impulse response estimates of the composite import price index and one standard deviation (SD) probability intervals 12 months after a one SD shock to the volatility of exchange rate shocks from a VAR à la Mumtaz and Zanetti (2013). Countries denoted by the two-digit ISO code. Aggregate prices (agg), prices of euro area imports (intra), and non-euro area imports (extra) [Colour figure can be viewed at [wileyonlinelibrary.com](#)]

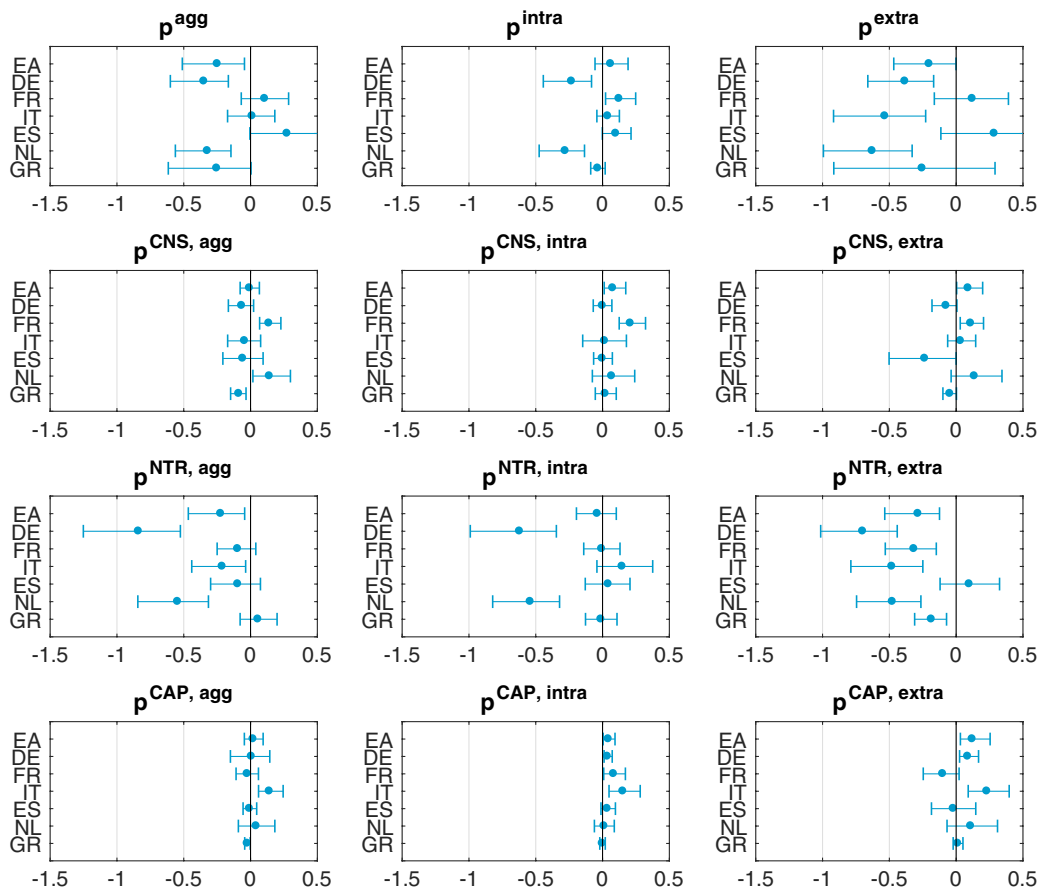


FIGURE 4 Responses of import prices' sub-indices following an exchange rate uncertainty shock. *Note:* Cumulative impulse response estimates of the composite import price index, consumer goods import price index (CNS), the intermediate goods price index (NTR), and the capital goods import price index (CAP) and one standard deviation (SD) probability intervals 12 months after a one SD shock to the volatility of exchange rate shocks from a stochastic volatility-in-mean VAR. Countries denoted by the two-digit ISO code. Aggregate prices (agg), prices of euro area imports (intra) and non-euro area imports (extra) [Colour figure can be viewed at [wileyonlinelibrary.com](#)]

area trade. Except for Germany and the Netherlands, p^{intra} do not react to exchange rate uncertainty shocks. 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 there is a fall in the intermediate goods, which has a larger effect than the opposite price dynamics of consumer goods.

The theoretical literature on exchange rate uncertainty and import prices suggests that the important factor behind the different price responses following the uncertainty shock is which party is bearing the exchange rate risk.

Earlier literature based on partial equilibrium analysis introduces exchange rate risk via incorporating contract leads and payment lags (Clark, 1973; Hooper & Kohlhagen, 1978). Thus “variations in future spot exchange rates induce fluctuations in the unhedged profit streams of international traders”.²³ The framework also allows for different risk appetites across importers and exporters. Depending on the invoicing currency of the contract, exchange rate risk is borne either by importers or exporters. If the risk is on the producer part, prices will rise with increasing volatility as potential negative exchange rate developments are priced in the contracts. If exchange rate risk is borne by the importers, exchange rate shocks affect the import demand. Domestic currency depreciation makes imports more expansive and import demand falls, hence import prices decline. In addition, 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 market share and perception of temporary and permanent shocks. Thus, firms with low market power are more prone to be the ones bearing the exchange rate risk, as they are price takers.

More recent studies based on general equilibrium studies such as Devereux and Engel (2002) and Corsetti et al. (2008) arrive to similar conclusions, even though through different means. Devereux and Engel (2002) propose a model in which exporters may choose to market their goods abroad directly, in which case they are affected by exchange rate volatility. However, if the foreign market is large, they choose to go through local distributors/importers. In that case, after the initial transaction exporter to importer, the currency risk is transferred to the local distributors who then repackage/resell the goods. This feature of the model, coupled with the nominal rigidities is a crucial aspect that explains the exchange rate disconnect puzzle and allows for high exchange rate volatility and low pass-through to coexist in the model, as they appear in the data.

These theoretical considerations give insight regarding the empirical findings. Falling intermediate goods' prices suggests that the risk is on the importers' side and that a larger share of currency invoicing is not in euro.²⁴ Given the nature of intermediate goods, our findings are also in line with the ideas of Devereux and Engel (2002). Intermediate goods are used further in the production chain. In that sense they are not “marketed directly” by the exporters and the currency risk is transferred to the importers. In this line of thought, the contrary appears to be true regarding consumer and capital goods where exporters are bearing the exchange rate risk. The invoicing currency is euro and a majority of these goods are sold directly by the producers.

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 periods. Therefore, we explore this avenue more thoroughly first. Second, we analyze the effects of the multivariate framework of our findings by integrating the effects of the stochastic volatility 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 owing 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 3 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 to 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.²⁵ 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 considered 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 5 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.²⁶

In this paper we explore the effects of exchange rate uncertainty on the pricing behavior of firms using a monthly dataset on industrial import prices for the euro area and six of its members. Using a nonlinear 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 not 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.

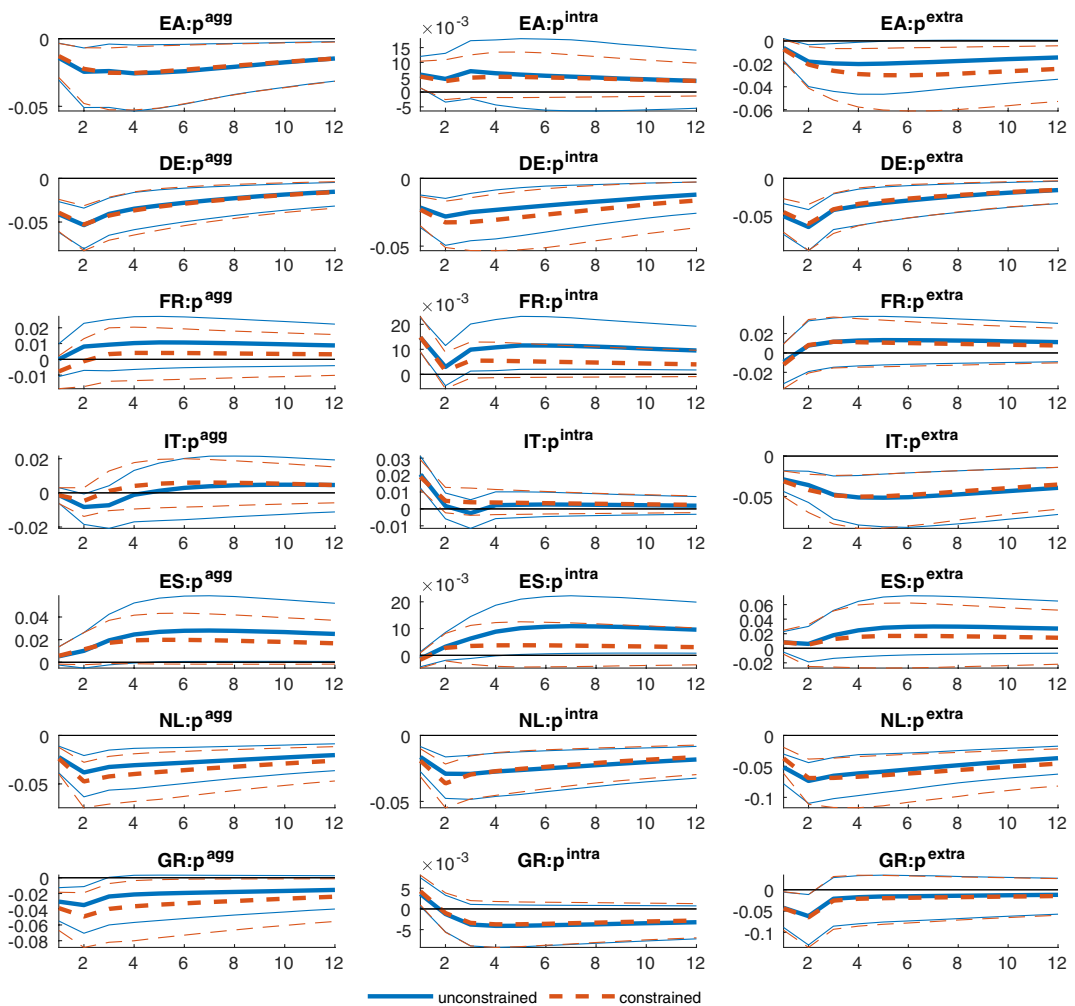


FIGURE 5 Impulse response functions: Constrained vs. unconstrained model. *Note:* Response of the composite import price index for aggregate, euro area and non-euro area imports following a change to the volatility of the exchange rate shocks. Unconstrained model as laid out in the previous section; constrained model presents the response to prices following the volatility change all else held equal [Colour figure can be viewed at wileyonlinelibrary.com]

5 | CONCLUSION

In this paper we explore the effects of exchange rate uncertainty on the pricing behavior 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 not 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 nonlinearities are an import part of the import price dynamics. From a policy perspective, the exchange rate volatility could be a channel for inflation, even when the exchange rate pass-through is low or nonexistent. Hence, exchange rate movements should be monitored by the monetary policy authority as a potential channel for inflation.

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ENDNOTES

¹ A variety of reasons have been proposed as to why the ERPT is small. Low inflationary environment and nominal rigidities have been highlighted to play an important role in the pricing of imports in a variety of studies, along with currency invoicing and the correlation structure of sales and costs (Bailliu & Fujii, 2004; Bouakez & Rebei, 2008; Bussiere, 2013; Campa & Goldberg, 2005; Choudhri & Hakura, 2006, 2015; Devereux, Dong, & Tomlin, 2017; Devereux & Engel, 2002; Devereux & Yetman, 2010; Enders, Enders, & Hoffmann, 2018; Gagnon & Ihrig, 2004; Gopinath, 2015; Özyurt, 2016; Shintani, Terada-Hagiwara, & Yabu, 2013; Taylor, 2000; Turner & Wood, 2017). However, there appears to be disagreement across the ERPT estimates. Country-specific factors, as well as problems with misspecification and the suboptimality of proxies for important determinants have been given as a reason why this might be the case (Corsetti et al., 2008; De Bandt et al., 2008; Forbes, Hjortsoe, & Nenova, 2018; Goldberg & Knetter, 1997; Osbat & Wagner, 2006). More recent studies have suggested that the ERPT is time varying and that it is higher during periods of macroeconomic instability (De Bandt & Razafindrabe, 2014; Donayre & Panovska, 2016; Nogueira & León-Ledesma, 2011).

² This definition coincides with popular definitions of uncertainty as the conditional volatility, that is, the unforecastable component of a series (e.g., Jurado, Ludvigson, & Ng, 2015). While the formal definition will be presented in Section 3, we will use the terms exchange rate uncertainty, volatility, and conditional volatility interchangeably.

³ The setup is similar to the GARCH-in-mean model of Kroner and Lastrapes (1993) with focus on import prices and addressed from a structural perspective.

⁴ To our knowledge the dataset has been used so far in the ERPT context only by De Bandt and Razafindrabe (2014) and only for the study of bilateral ERPT towards the U.S. dollar, the British pound and the Chinese renminbi. They use the data until June 2013.

⁵ De Bandt, Banerjee, and Kozluk (2008) provide an excellent discussion of the limitations of unit-value indices.

⁶ Data for Lithuania and Slovakia start in 2009 and 2015, respectively. Both countries have adopted the euro later, hence they are excluded from the analysis.

- ⁷ This contrasts with unit value indices (UVI), which are expressed as price per tonne, for example, a price index for personal computers is tracked per unit of weight and hence reflects not only price changes but also quantity and quality variations over time.
- ⁸ 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).
- ⁹ See Figure A1 in the Appendix for the evolution of intra- and extra-euro area trade shares in the EU28. The shares do not exhibit large variations, hence their contribution to the time-varying ERPT estimates in practice is probably low.
- ¹⁰ The results are available upon request.
- ¹¹ For the data sources see the Appendix, Section A3.
- ¹² We provide long-run estimates, since other studies are in quarterly frequency and short-run estimates are not directly comparable.
- ¹³ A selection of ERPT papers and long-run estimates is available in Table A4 of the Appendix, Section A5.
- ¹⁴ Third market effects arise when changes in the bilateral exchange rate with a third country warrant competitors to adjust their prices. For example, German car manufacturers exporting in Greece might have to respond to yen–euro movements if Japanese car manufacturers change their prices on the Greek car market.
- ¹⁵ 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 & Bollerslev, 1989). Specifically the GARCH-in-mean models have also been employed in the ERPT literature (Grier & Smallwood, 2013; Kroner & Lastrapes, 1993; Ozkan & Erden, 2015; Straub & Tchakarov, 2004). Intuitively, the conditional volatility captures the variability of the unforecastable component of a time series, which is a common definition of uncertainty (Jurado et al., 2015).
- ¹⁶ For a discussion of one-step vs. two-step estimations of uncertainty indices see (Bianchi, Kung, & Tirskikh, 2018).
- ¹⁷ That is not to say that the VAR framework is free from assumptions. Specifically, the choice of data and the lag specification also play a crucial role, which is why in what follows we take all these choices following econometric methods. Moreover, futures contracts may be used to extract a measure of implied volatility as opposed to a volatility measure based on realized values.
- ¹⁸ As pointed out by Forbes et al. (2018), the exchange rate is in most part a purely endogenous variable, which is driven by supply and demand shocks. In that respect our model is much closer to the earlier literature on ERPT.
- ¹⁹ The position of y relative to Δe^* 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. We also change the order of e and p and do not find any significant changes in the estimates. The results are available upon request.
- ²⁰ In the interest of space, we present the results for the aggregate composite index p^{agg} only. The other estimates are highly similar.
- ²¹ It should also be noted that normalizing 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.
- ²² The IRFs of the import prices are in Section A6 in the Appendix, Figures A3–A6. For completeness we also include the responses of all variables in Section A7, Figures A7–A11.
- ²³ Hooper and Kohlhagen (1978, p. 484).
- ²⁴ The data on currency invoicing cannot be mapped one-to-one with our dataset, as it is only available at the broadest SITC level. According to Eurostat, currency invoicing in euro in manufactured goods for extra-euro area trade is between 45% and 50% for the countries in our sample and about as equal a portion is stipulated in U.S. dollars.
- ²⁵ Results are available upon request.
- ²⁶ In the interest of space, we relegate the subgroups' IRFs to the Appendix, Section A8, Figures A11–A13.
- ²⁷ For example, supply and demand theory suggests a tight relationship between price and quantity, which in this specification relates to industrial production and industrial production prices. In the context of ERPT and depending on the

dataset several studies find evidence for, and model, cointegration explicitly (Arsova, 2019; Brun-Aguerre & Fuertes, 2012; Cheikh & Louhichi, 2015; De Bandt et al., 2008).

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APPENDIX

A1 | 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 starch 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 nonmetallic 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.

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.

Nondurable 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.

A2 | Share of imports by country of origin and invoice currency

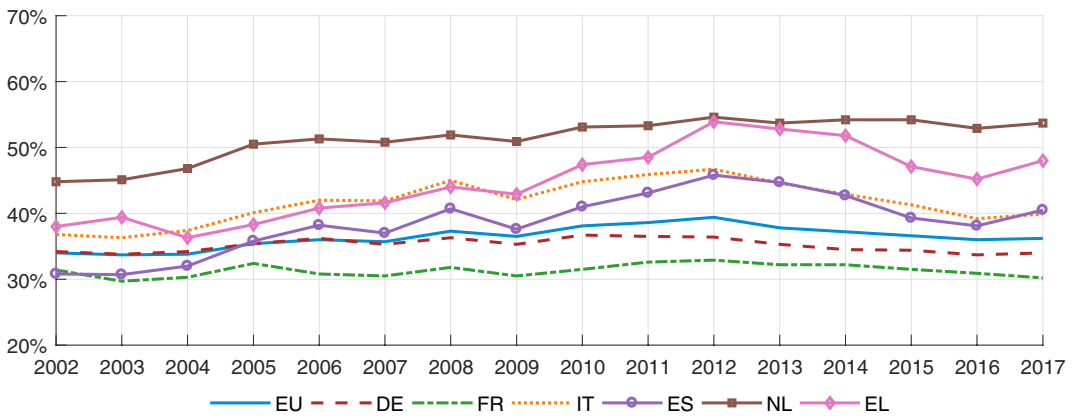


FIGURE A1 Percentage share of extra EU28 imports to total imports. *Note:* Volume of imports coming from outside the EU28 divided by the total volume of imports per country. *Source:* Eurostat [Colour figure can be viewed at wileyonlinelibrary.com]

A3 | Data sources and statistical properties

The replication codes and all relevant material needed to generate the results in this article are available online at http://borisblagov.com/publication/2019_eru/.

The data that support the findings of this study are from Eurostat at <https://ec.europa.eu/eurostat/data/database> reference numbers [sts_inpi_m] and [prc_hicp_midx] and from the IMF's International Financial Statistics at <http://data.imf.org/?sk=4C514D48-B6BA-49ED-8AB9-52B0C1A0179B>. These data were derived from the following resources available in the public domain:

http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=sts_inpi_m&lang=en

http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=prc_hicp_midx&lang=en

<http://data.imf.org/?sk=4C514D48-B6BA-49ED-8AB9-52B0C1A0179B&sid=1409151240976>

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 were from the international financial statistics of the IMF. All data have been

downloaded through the Macrobond software and, where appropriate, seasonally adjusted using the X-13 procedure in Eviews.

For the users of Macrobond, the codes to the publicly available data are given in Table A1.

Alternatively, one may use the NEER data from the ECB. The data are highly similar (correlation in first differences 0.98) but not identical. We plot NEER from the IMF and from the ECB on Figure A2.

Statistical properties

According to an augmented Dickey–Fuller test the series are $I(1)$ in levels and $I(0)$ in first differences. In Section 2.2 we estimate an ARDL model for the ERPT in log-differences in order to gauge how our dataset performs in the context of the ERPT literature. However, differencing could destroy additional information present in the levels such as a potential long-run relationship between import prices and nominal exchange rates and hence the reduced-form ERPT estimate will not take it into account. While the results are compared with reference studies that also do not consider cointegration,

TABLE A1 Macrobond codes for the data

Variable	Macrobond codes
Import prices in industry, total market	imprb_dnsai15XX19ii
Import prices in industry, total market, MIG—Capital goods, 2015 = 100, Index	imprmgcagnsai15XX19ii
Import prices in industry, total market, MIG—Consumer goods, 2015 = 100, Index	imprmgcognsai15XX19ii
Import prices in industry, total market, MIG—Intermediate goods, 2015 = 100, Index	imprmgingsai15XX19ii
Import prices in industry, non-euro area market, 2015 = 100, Index	impxb_dnsai15XX19ii
Import prices in industry, non-euro area market, MIG—Capital goods, 2015 = 100, Index	impxmgcagnsai15XX19ii
Import prices in industry, non-euro area market, MIG—Consumer goods, 2015 = 100, Index	impxmgcognsai15XX19ii
Import prices in industry, non-euro area market, MIG—Intermediate goods, 2015 = 100, Index	impxmgingsai15XX19ii
Import prices in industry, euro area market, MIG—Capital goods, 2015 = 100, Index	impzmgcagnsai15XX19ii
Import prices in industry, euro area market, MIG—Consumer goods, 2015 = 100, Index	impzmgcognsai15XX19ii
Import prices in industry, euro area market, MIG—Intermediate goods, 2015 = 100, Index	impzmgingsai15XX19ii
HICP, All-items HICP, 2015 = 100, Index	i15cp00XXdx
Industrial production, total industry excluding construction, Index	XXprod0001
IMF IFS, Financial sector, exchange rates, nominal effective exchange rate, based on CPI	imfmYYYeneer_ix
IMF IFS, Financial sector, exchange rates, real effective exchange rate, based on CPI	imfmYYYereer_ix
Import prices in industry, euro area market	impzb_dnsai15XX19ii

Note: Macrobond codes for the data. Replace “XX” in the codes with the two-digit ISO code: EA, DE, FR, ES, IT, NL, EL. Note that Greece's code in Eurostat's database is “EL”. Replace YYY in the IMF data with the following country codes: 163 for EA19, 134 for Germany, 132 for France, 136 for Italy, 184 for Spain, 138 for the Netherlands, and 174 for Greece.

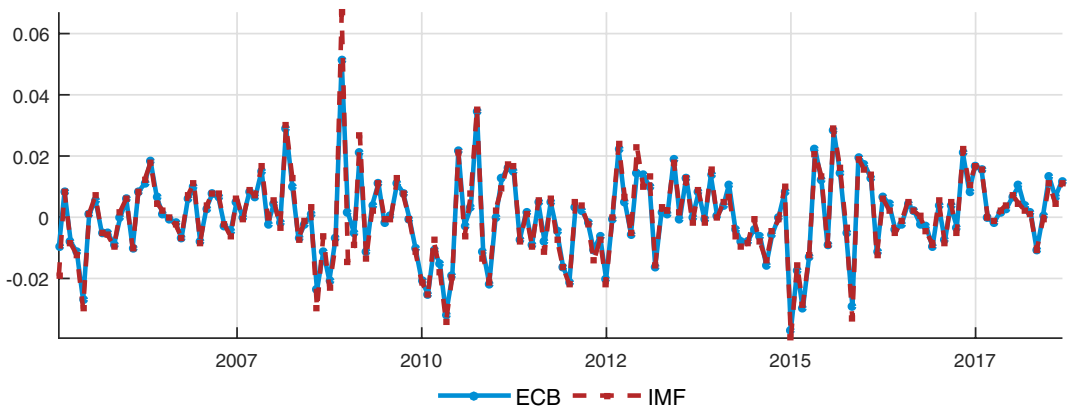


FIGURE A2 Comparison of NEER data from the ECB vs. the IMF. *Source:* Eurostat and IMF, obtained through Macrobond [Colour figure can be viewed at wileyonlinelibrary.com]

it is important to know whether this dataset is more informative on that topic. For such a relationship to exist, Equation 4 estimated in levels (or its form where p is regressed only on e would yield a stationary residual series. Using the two-step procedure by Engle and Granger we find overwhelming evidence that there is no cointegration present and thus the coefficients in Equation 4 contain the full information regarding a reduced-form ERPT estimate (see the left panel of Table A2).

The focus of this paper, however, is on the relation between exchange rate uncertainty and import prices. Cointegration testing for the structural analysis in Section 3 is more complicated. The variables in the VAR model could give rise to multiple linear combinations that yield stationary residuals suggesting one, if not many long-run relationships between the variables.²⁷ However, the asymptotic

TABLE A2 Univariate and multivariate cointegration tests

	EA	DE	FR	IT	ES	NL	GR	EA	DE	FR	IT	ES	NL	GR
p^{agg}	0	0	0	0	0	0	0	0	0	0	0	0	0	0
p^{intra}	0	0	0	1	1	0	1	0	0	0	1	1	0	1
p^{extra}	0	0	0	0	0	0	0	0	0	0	0	0	0	0
$p^{CNS,agg}$	0	1	0	2	1	1	1	0	1	0	2	1	1	1
$p^{CNS,intra}$	0	0	0	1	1	2	1	0	0	0	1	1	2	1
$p^{CNS,extra}$	0	0	1	1	0	1	0	0	0	1	1	0	1	0
$p^{NTR,agg}$	0	0	0	0	0	0	0	0	0	0	0	0	0	0
$p^{NTR,intra}$	0	0	0	0	0	0	0	0	0	0	0	0	0	0
$p^{NTR,extra}$	0	0	0	0	1	0	1	0	0	0	0	1	0	1
$p^{CAP,agg}$	0	1	0	1	0	1	0	0	1	0	1	0	1	0
$p^{CAP,intra}$	1	0	0	1	0	1	0	1	0	0	1	0	1	0
$p^{CAP,extra}$	1	1	0	2	0	1	0	1	1	0	2	0	1	0

Note: Left table: Engle and Granger cointegration test of the regression of import prices as a function of NEER, industrial production and foreign producers' costs in levels. A "1" indicates a rejection of the null hypothesis of *no cointegration* at the 5% significance level (p value < 0.05). The model selection and lag order has been carried out via the Schwarz information criteria (SIC). Right table: Johansen test for the maximum number of cointegration relationships (p value < 0.05) of a multivariate system comprising of import prices, NEER, industrial production and foreign producers' costs.

results of the standard multivariate tests, for example Johansen's test, are not valid for a model in the form of Equation 5 and could not be used for assessing a potential cointegrating relationship between the structural shocks of the exchange rate and the import prices.

With this known caveat, testing a linear VAR with Johansen's test, we report the number of cointegrating relationships at p value < 0.05 in the right panel of Table A2. The test does not reject as overwhelmingly as the univariate test. In about 30% of all cases at least one cointegration relationship is significant at the 5% level (at the 1% level only five cases remain significant) and the cases are primarily concentrated in the Italian and Dutch data for consumer and capital goods. While most of these findings disappear at the 1% level we do suggest taking those respective estimates of exchange rate uncertainty with a grain of salt.

A4 | 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 favors 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 A3 summarizes the results. There are only a few differences compared with 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

TABLE A3 Long-run exchange rate pass-through estimates

Endogenous variable	EA	DE	FR	IT	ES	NL	GR
<i>Composite price index</i>							
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
<i>Consumer good prices</i>							
$p^{CNS,agg}$	-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*
<i>Intermediate goods prices</i>							
$p^{NTR,agg}$	-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
<i>Capital good prices</i>							
$p^{CAP,agg}$	-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

Note: Estimates of long-run ERPT, changes to import prices following a one percent appreciation of the nominal exchange rate. In percentage points. 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 two-digit ISO code, are euro area 19 (EA), Germany (DE), France (FR), Italy (IT), Spain (ES), the Netherlands (NL), and Greece (GR). An asterisk (*) indicates significance at the 5% level.

similar overall. The most notable difference 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 most 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 an insignificant long-run estimate.

A5 | Long-run ERPT estimates from a selection of studies

TABLE A4 Sample of long-run exchange rate pass-through estimates

	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) ^a	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) ^b	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) ^c	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	

Note: Comparison of exchange rate pass-through estimates. Changes to the price level, as proxied by different dependent variables (Dep.), in response to a 1% 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 prices; P^{IMP_{NEA}} is the import price deflator of non-euro area goods and services; the countries are given by two-digit ISO code.

^aThe beginning year of the subsample ranges from 1981 for Germany until 1994 for Greece.

^bPass-through estimated at SITC level, values are averages.

^cReported the estimates for 1 year ahead.

A6 | Exchange rate uncertainty IRFs of import prices

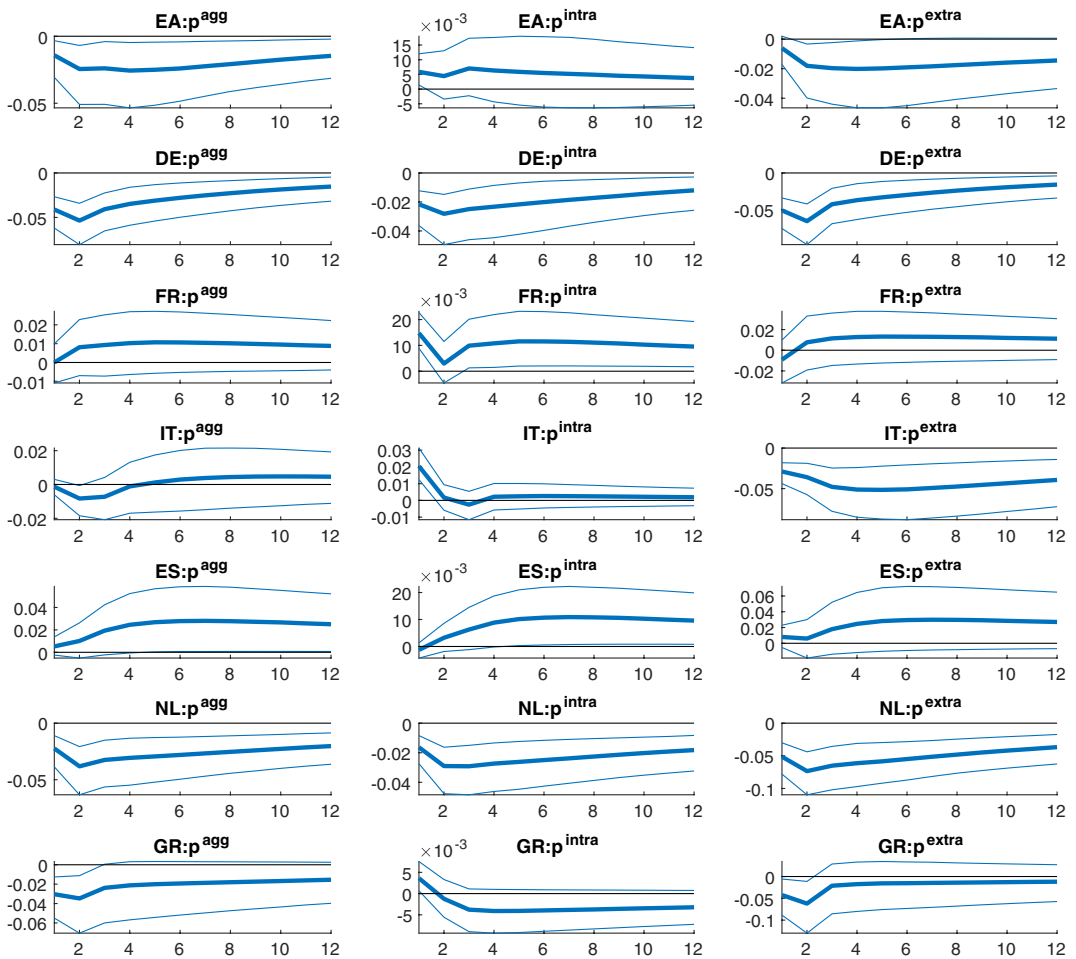


FIGURE A3 Composite import price index following a volatility shock to the exchange rate. *Note:* Impulse responses of the composite import price index (CMP) and one standard deviation (SD) probability intervals following a shock to the volatility of exchange rate shocks from a VAR *à la* Mumtaz and Zanetti (2013). Countries denoted by the two-digit ISO code. Aggregate prices, prices of euro area imports (intra), and non-euro area imports (extra) [Colour figure can be viewed at wileyonlinelibrary.com]

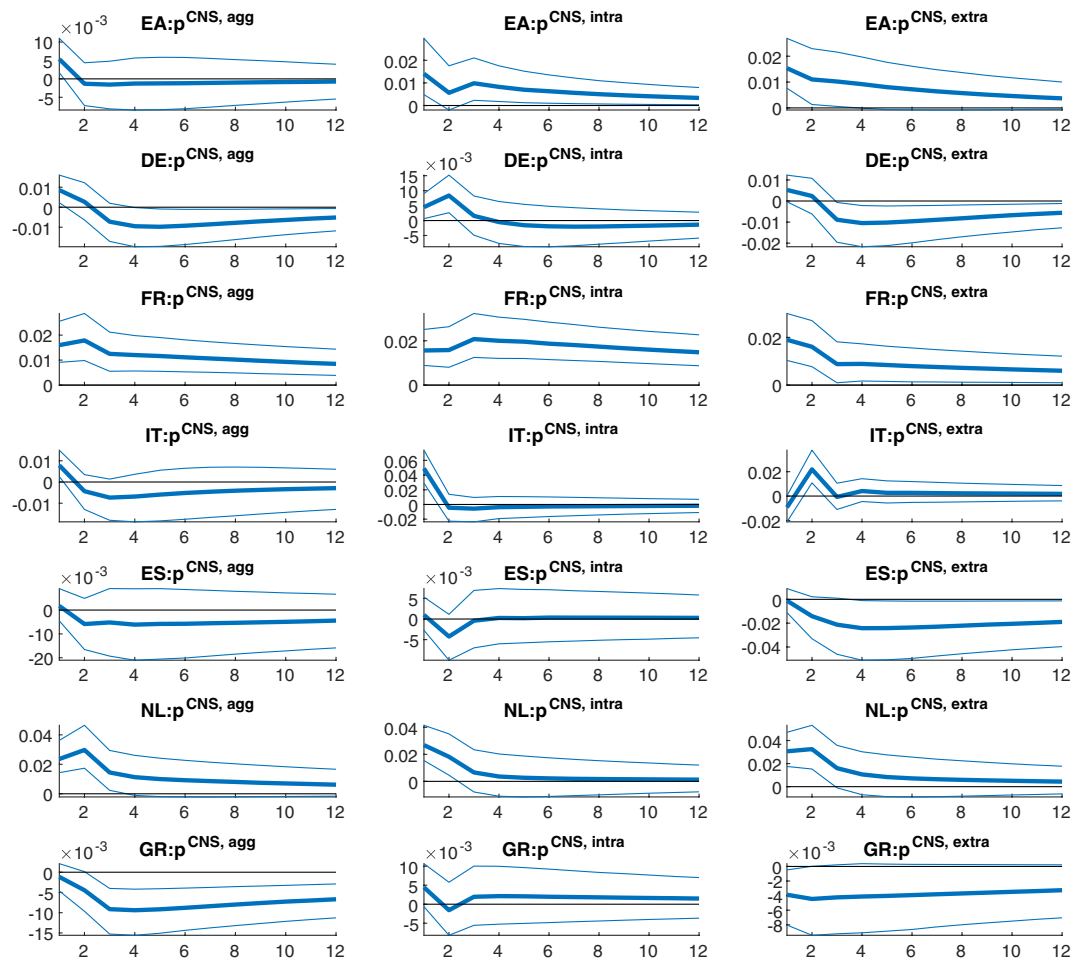


FIGURE A4 Consumer goods' import price index following a volatility shock to the exchange rate. *Note:* Impulse responses of the composite import price index (CNS) and one standard deviation (SD) probability intervals following a shock to the volatility of exchange rate shocks from a VAR *à la* Mumtaz and Zanetti (2013). Countries denoted by the two-digit ISO code. Aggregate prices, prices of euro area imports (intra), and non-euro area imports (extra) [Colour figure can be viewed at wileyonlinelibrary.com]

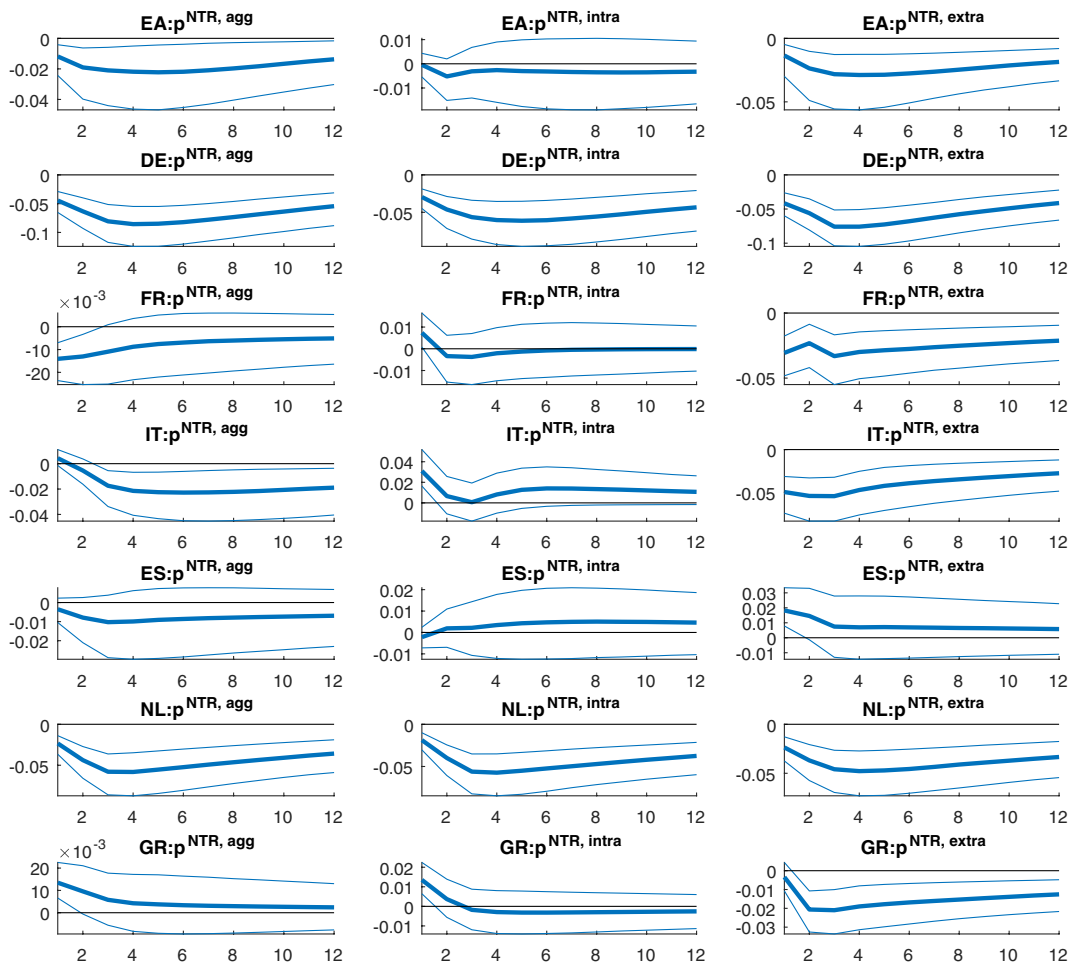


FIGURE A5 Intermediate goods' import price index following a volatility shock to the exchange rate. *Note:* Impulse responses of the composite import price index (NTR) and one standard deviation (SD) probability intervals following a shock to the volatility of exchange rate shocks from a VAR à la Mumtaz and Zanetti (2013). Countries denoted by the two-digit ISO code. Aggregate prices, prices of euro area imports (intra), and non-euro area imports (extra) [Colour figure can be viewed at wileyonlinelibrary.com]

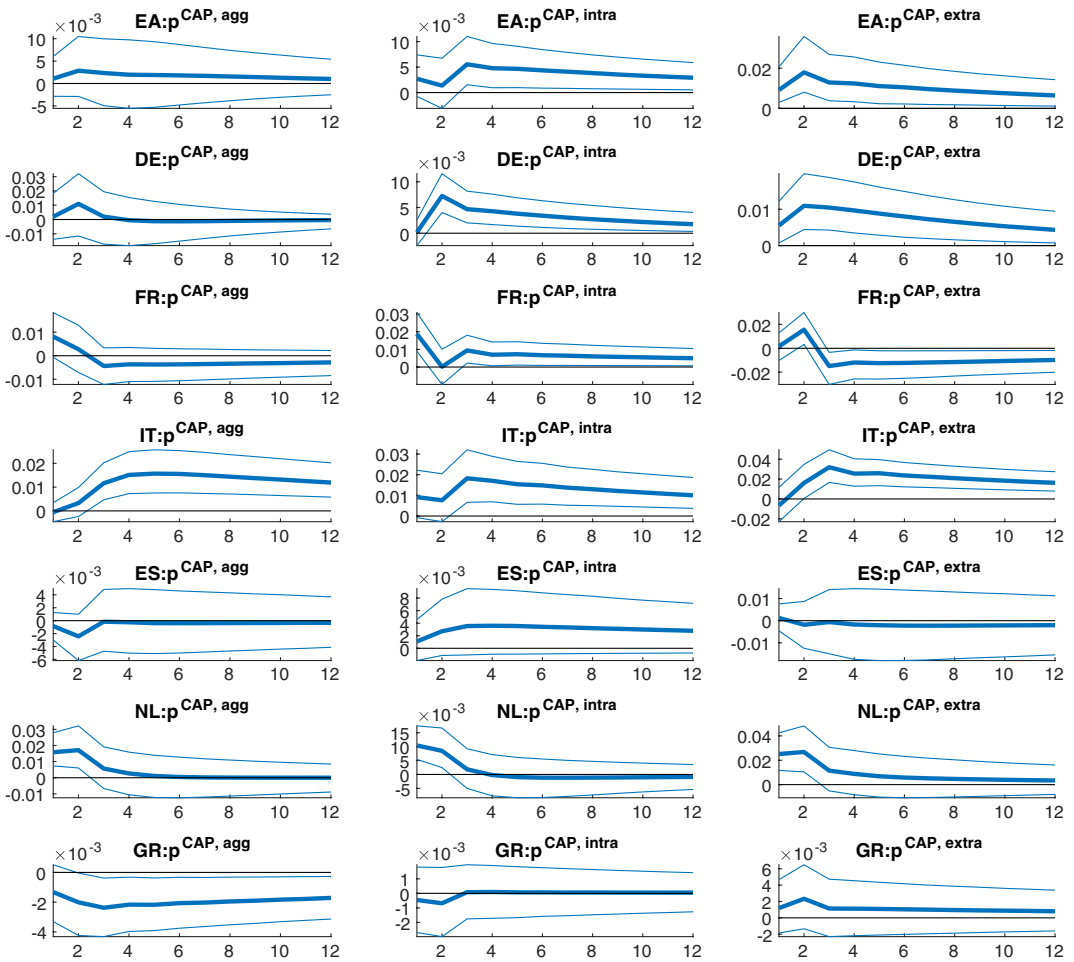


FIGURE A6 Capital goods' import price index following a volatility shock to the exchange rate. *Note:* Impulse responses of the composite import price index (CAP) and one standard deviation (SD) probability intervals following a shock to the volatility of exchange rate shocks from a VAR *à la* Mumtaz and Zanetti (2013). Countries denoted by the two-digit ISO code. Aggregate prices, prices of euro area imports (intra), and non-euro area imports (extra) [Colour figure can be viewed at wileyonlinelibrary.com]

A7 | Exchange rate uncertainty full IRFs

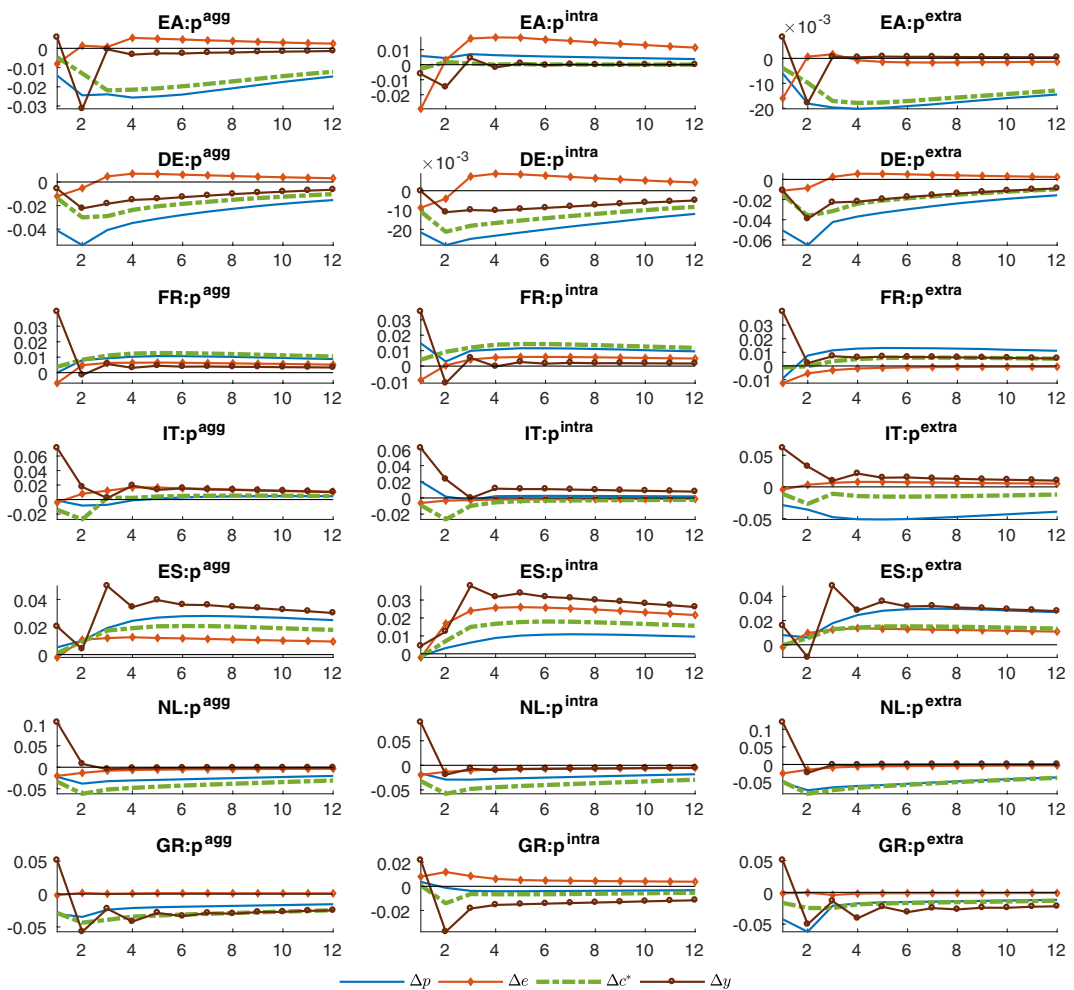


FIGURE A7 Impulse responses following a volatility shock to the exchange rate of the models with the composite import price indices. *Note:* Impulse responses of the composite import price index (p), nominal effective exchange rate (e), producer's cost proxy (c^*), and industrial production (y), following a shock to the volatility of exchange rate shocks from a VAR *à la* Mumtaz and Zanetti (2013). Countries denoted by the two-digit ISO code. Aggregate prices (agg), prices of euro area imports (intra), and non-euro area imports (extra) [Colour figure can be viewed at wileyonlinelibrary.com]

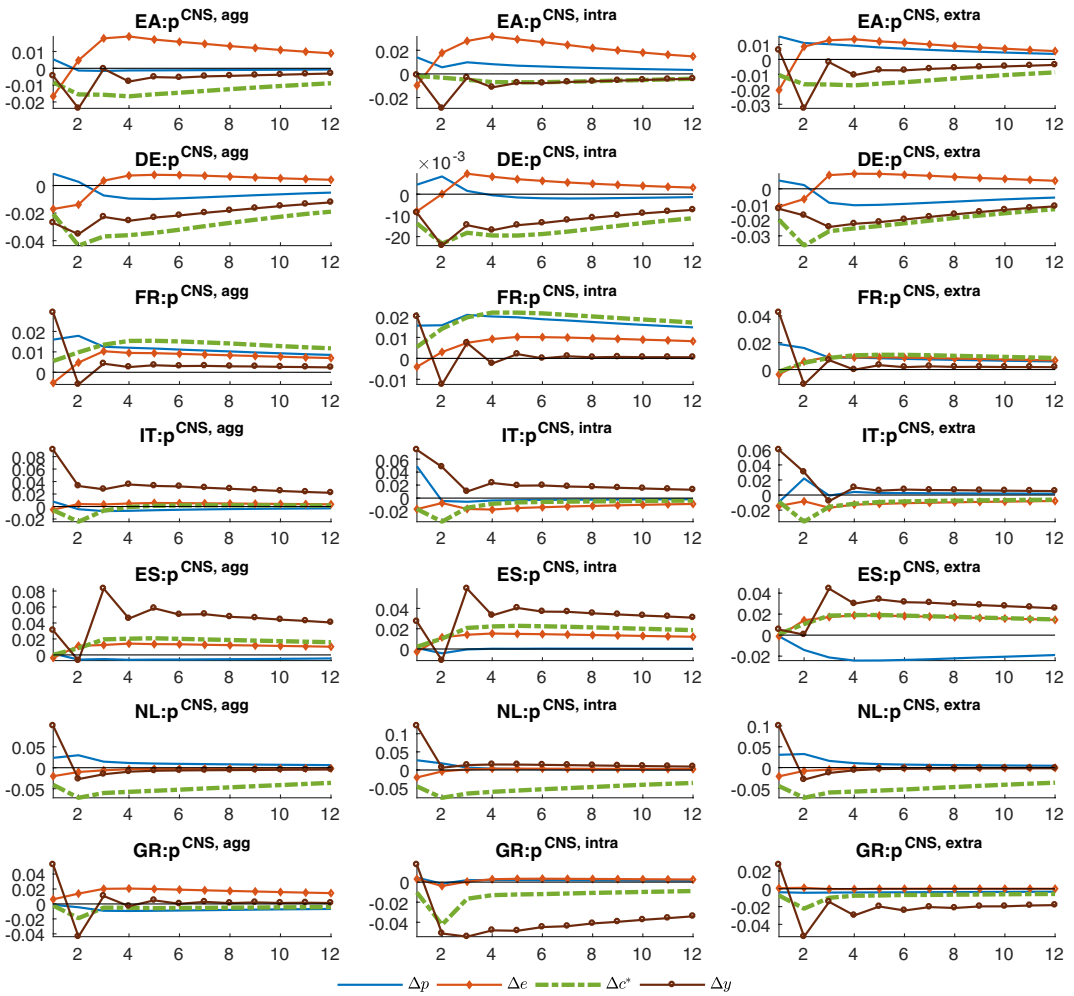


FIGURE A8 Impulse responses following a volatility shock to the exchange rate of the models with the consumer goods' import price indices. *Note:* Impulse responses of the consumer goods import price index (p^{CNS}), nominal effective exchange rate (e), producer's cost proxy (c^*), and industrial production (y), following a shock to the volatility of exchange rate shocks from a VAR *à la* Mumtaz and Zanetti (2013). Countries denoted by the two-digit ISO code. Aggregate prices (agg), prices of euro area imports (intra), and non-euro area imports (extra) [Colour figure can be viewed at wileyonlinelibrary.com]

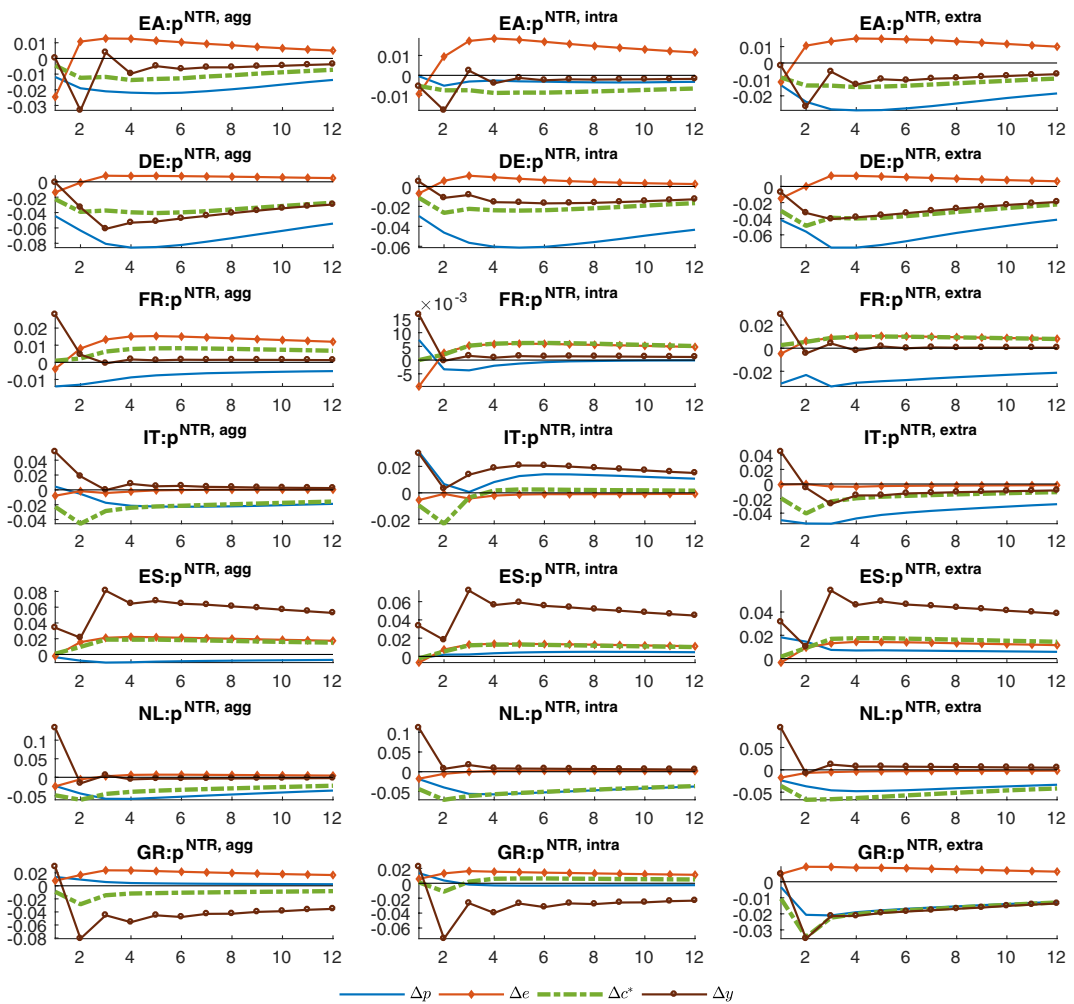


FIGURE A9 Impulse responses following a volatility shock to the exchange rate of the models with the intermediate goods' import price indices. *Note:* Impulse responses of the intermediate goods import price index (p^{NTR}), nominal effective exchange rate (e), producer's cost proxy (c^*), and industrial production (y), following a shock to the volatility of exchange rate shocks from a VAR *à la* Mumtaz and Zanetti (2013). Countries denoted by the two-digit ISO code. Aggregate prices (agg), prices of euro area imports (intra), and non-euro area imports (extra) [Colour figure can be viewed at wileyonlinelibrary.com]

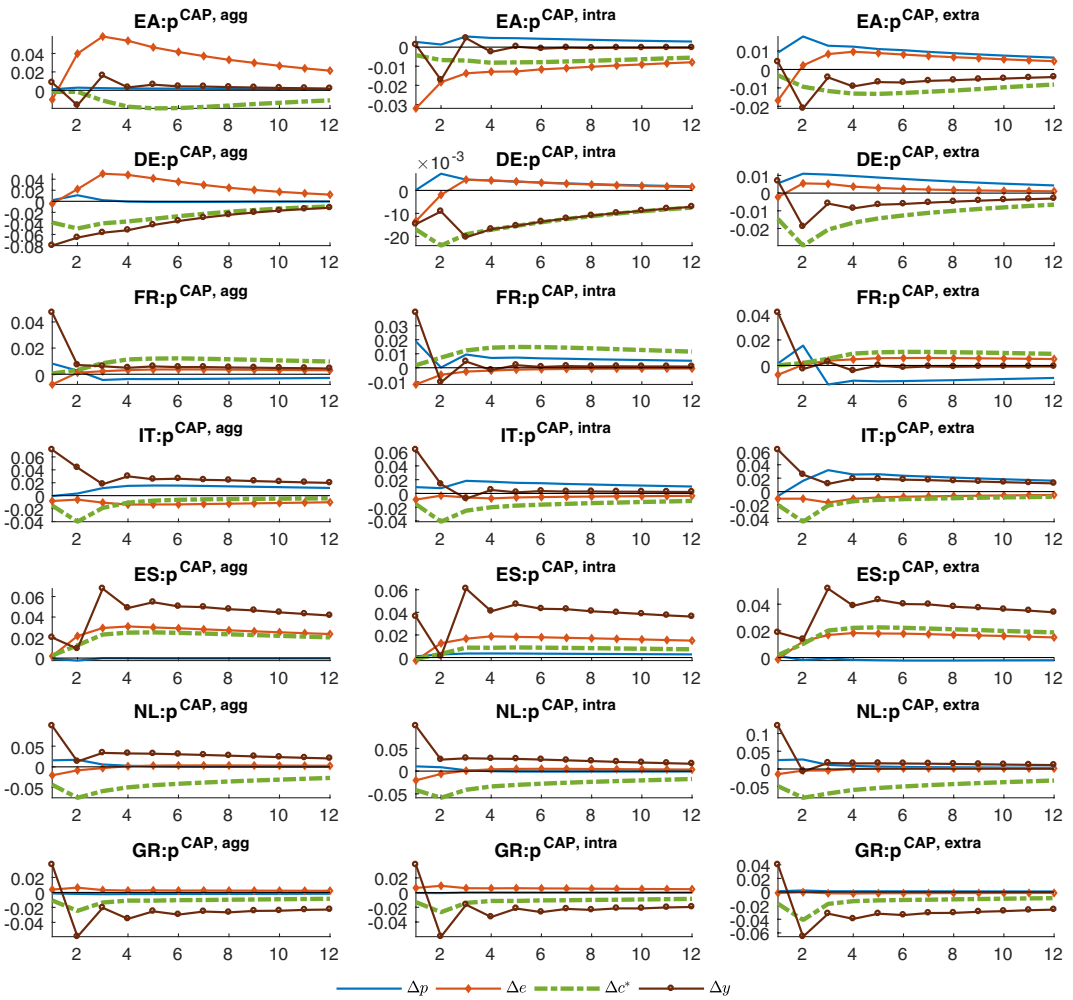


FIGURE A10 Impulse responses following a volatility shock to the exchange rate of the models with the capital goods' import price indices. *Note:* Impulse responses of the capital goods import price index (p^{CAP}), nominal effective exchange rate (e), producer's cost proxy (c^*), and industrial production (y), following a shock to the volatility of exchange rate shocks from a VAR *à la* Mumtaz and Zanetti (2013). Countries denoted by the two-digit ISO code. Aggregate prices (agg), prices of euro area imports (intra), and non-euro area imports (extra) [Colour figure can be viewed at wileyonlinelibrary.com]

A8 | Constrained versus unconstrained models' IRF

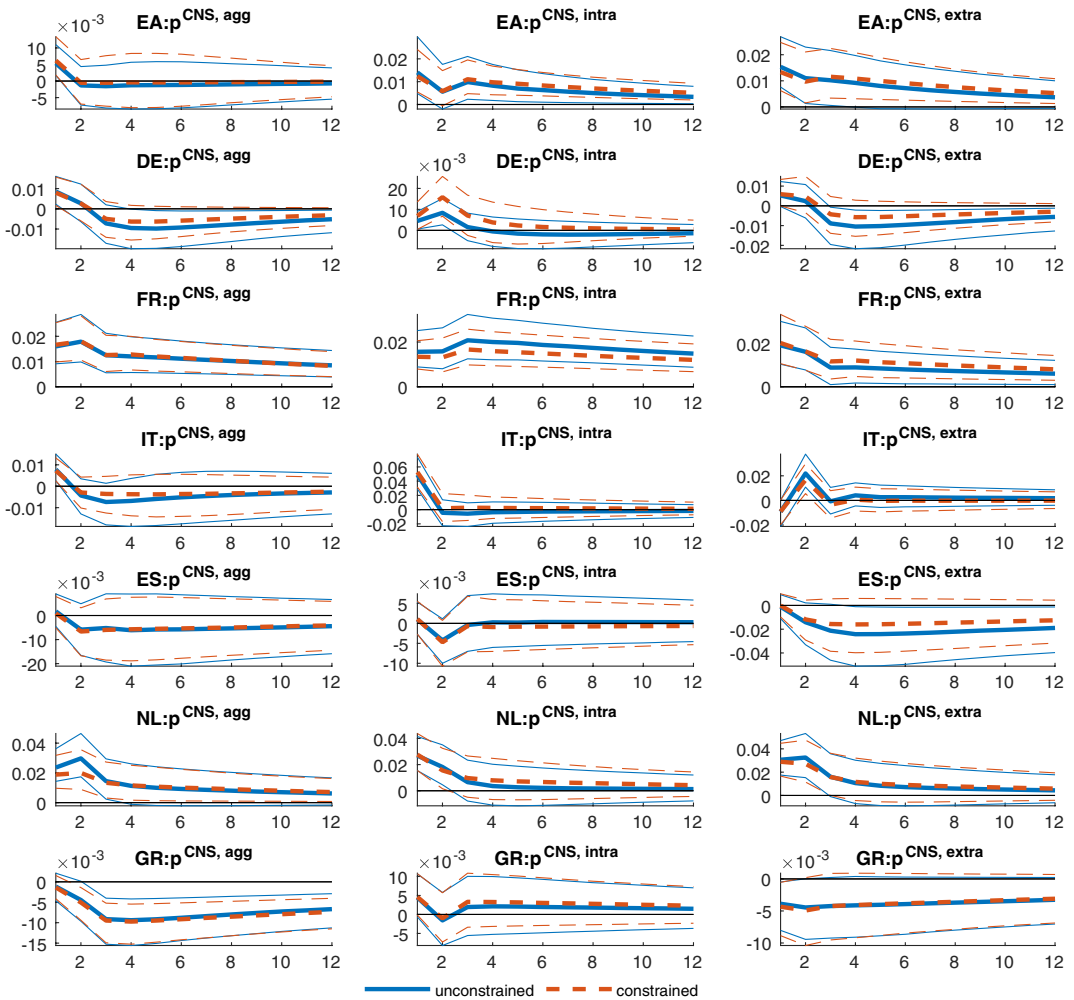


FIGURE A11 Impulse response functions: constrained vs. unconstrained models. *Note:* Response of the consumption goods' import price index for aggregate, euro area and non-euro area imports following a change to the volatility of the exchange rate shocks. Unconstrained model as laid out in Section 3; constrained model presents the response to prices following the volatility change all else held equal [Colour figure can be viewed at wileyonlinelibrary.com]

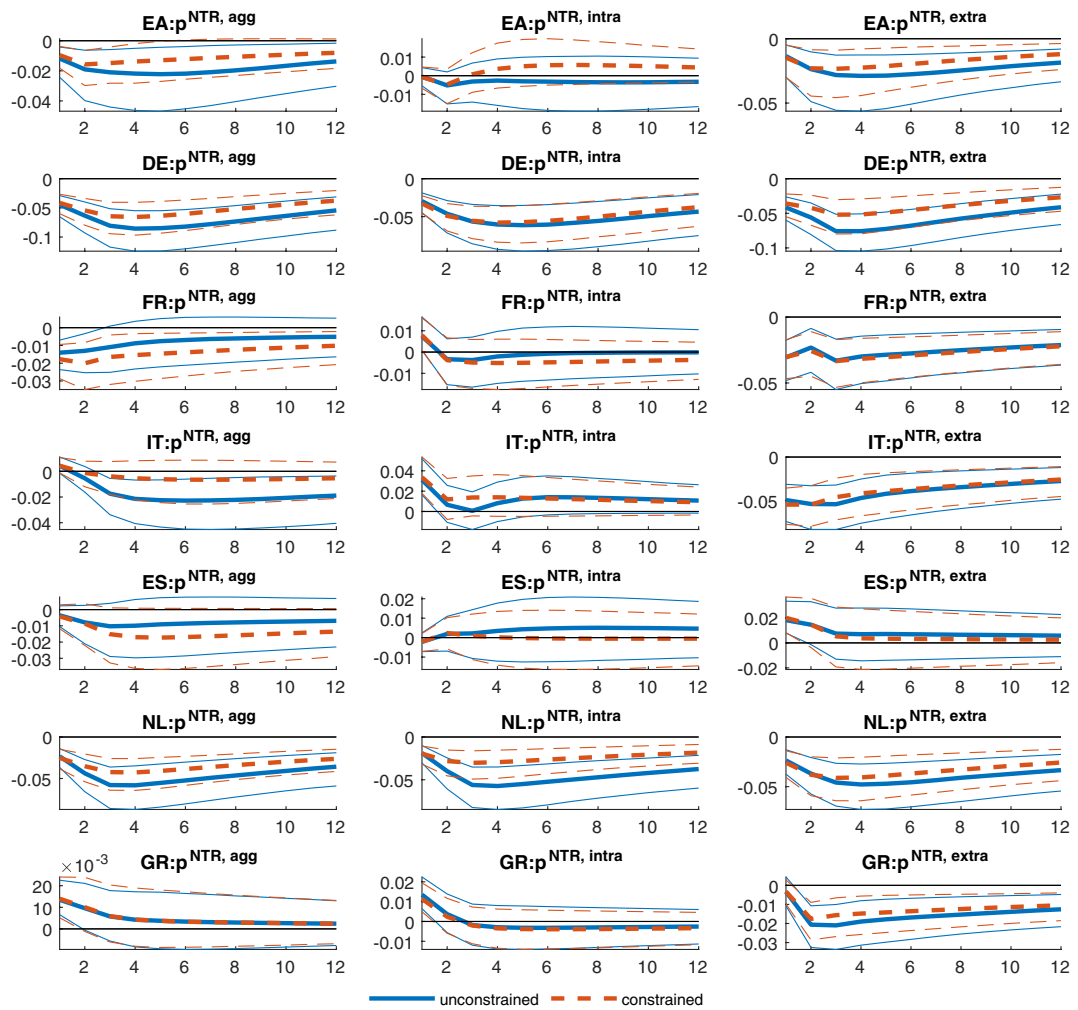


FIGURE A12 Impulse response functions: constrained vs. unconstrained models. *Note:* Response of the intermediate goods' import price index for aggregate, euro area and non-euro area imports following a change to the volatility of the exchange rate shocks. Unconstrained model as laid out in Section 3; constrained model presents the response to prices following the volatility change all else held equal [Colour figure can be viewed at wileyonlinelibrary.com]

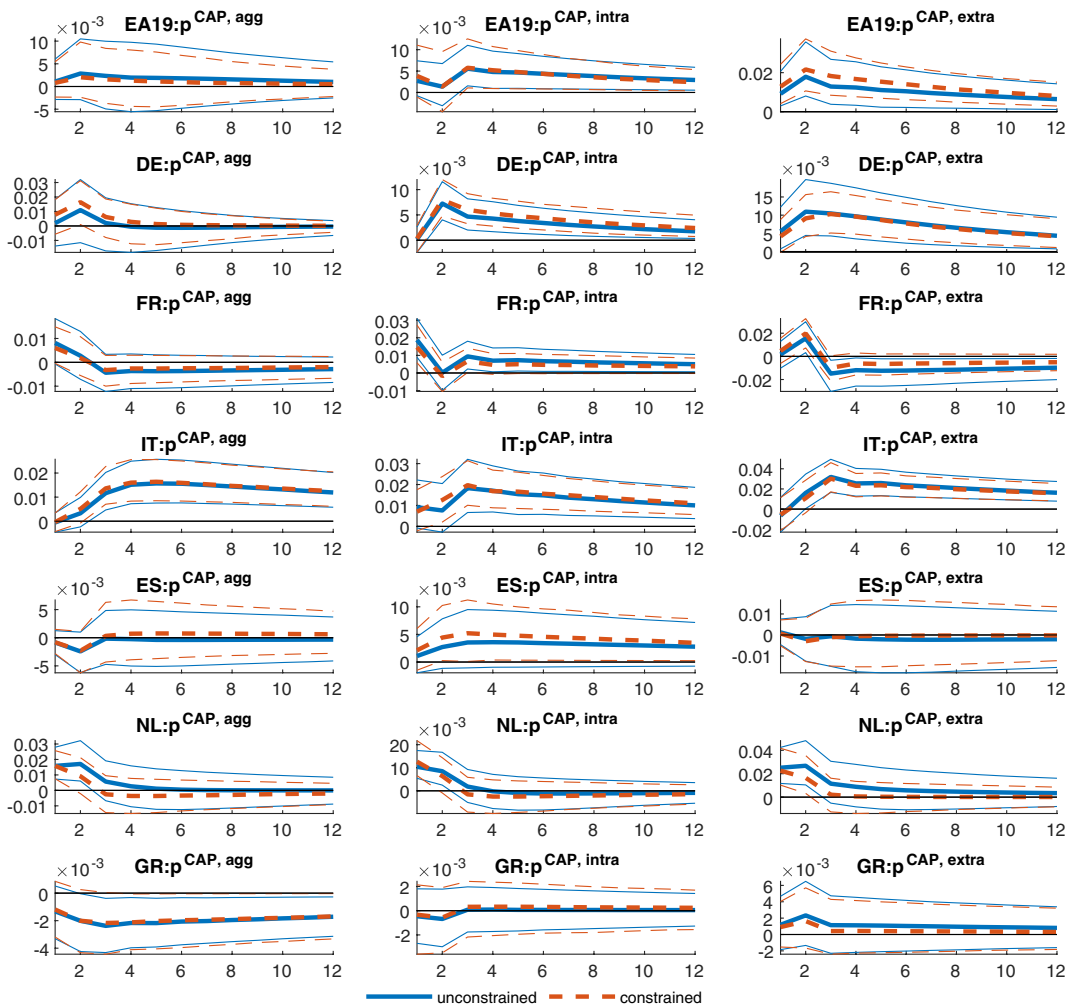


FIGURE A13 Impulse response functions: constrained vs. unconstrained models. *Note:* Response of the capital goods' import price index for aggregate, euro area and non-euro area imports following a change to the volatility of the exchange rate shocks. Unconstrained model as laid out in Section 3; constrained model presents the response to prices following the volatility change all else held equal [Colour figure can be viewed at wileyonlinelibrary.com]