EUROPEAN CENTRAL BANK
EUROSYSTEM

Working Paper Series

Roberta Colavecchio, Ieva Rubene

Non-linear exchange rate pass-through to euro area inflation: a local projection approach

No 2362 / January 2020

Abstract

How long does it take for exchange rate changes to pass through into inflation? Does it make a difference whether the exchange rate depreciates or appreciates? Do relatively large exchange rate changes entail more exchange rate pass-through? In this paper, we examine possible non-linearities in the transmission of exchange rate movements to import and consumer prices in all 19 euro area countries as well as the euro area as a whole from 1997 to 2019Q1. We extend a standard single-equation linear framework with additional interaction terms to account for possible non-linearities and apply local projections to obtain state-dependent impulse response functions. We find that (i) euro area consumer and import prices respond significantly to exchange rate movements after one year, responding more when the exchange rate change is relatively large; and (ii) euro appreciations and depreciations affect the level of euro area exchange rate pass-through in a symmetric fashion; (iii) for euro area countries results differ for import and consumer prices and across countries.

JEL Classification: E31, F41.

Keywords: Exchange Rate Pass-Through; Inflation; Local Projections; Non-Linearities.

Non-Technical Summary

The degree to which exchange rate changes are transmitted to import prices and subsequently to final consumer prices is commonly referred to as "exchange rate pass-through" (ERPT). The literature on ERPT suggests theoretical underpinnings and provides some empirical evidence for the presence of non-linearities. These may reflect downward rigidities in prices, binding capacity constraints, market share strategies, menu costs, the choice of invoicing currency, the state of the business cycle or the level and variability of inflation. Few empirical studies consider non-linear responses of prices to exchange rate changes, especially for the euro area. This paper contributes to this literature and examines two types of non-linearities in ERPT, summarised by the following questions: does it make a difference if the exchange rate depreciates or appreciates? What if the exchange rate change is relatively large from a historical perspective – does this entail more exchange rate pass-through?

The empirical exercise is conducted with the country-specific harmonized index of consumer prices and the aggregate import price index at the border, using quarterly data from 1997Q1 to 2019Q1 for all 19 euro area countries and the euro area as a whole. The analysis extends a standard single-equation linear framework with additional interaction terms to account for possible non-linearities and applies local projection (LP) techniques to obtain state-dependent impulse response functions. Due to the relatively short estimation sample available and to the intrinsic limitations of the LP estimator, the uncertainty surrounding the estimated price responses to exchange rate changes is particularly large at distant forecasting horizons.

Evidence for the euro area as a whole suggests that import prices respond significantly more to exchange rate movements that are relatively large. However, the *size* non-linearity is relatively short-lived, disappearing at the two-year horizon. Consumer prices also respond more to large exchange rate changes, while their response to small changes is not significant. We find no evidence that euro appreciations and depreciations affect consumer or import price inflation in an asymmetric fashion, that is, exchange rate changes of opposite sign lead to price responses that are not statistically different. We therefore conclude that the *size* rather than the *sign* of exchange rate changes significantly affects the level of ERPT to import and consumer prices in the euro area as a whole.

For euro area countries, our estimates suggest that import prices respond only partially, on impact, to exchange rate changes, possibly because our measure of import prices includes intra-euro area trade. The degree of ERPT to consumer prices differs substantially across countries, but is always very small. We find evidence of non-linear ERPT in a number of euro area countries. Some larger euro area countries display significantly larger ERPT to import prices following euro appreciation than depreciations, but only at shorter horizons. Finally, the price response to large and small exchange rate movements is heterogeneous and country-specific. In some countries prices respond to relatively small exchange rate changes, in others the response is only significant for large exchange rate changes.

1 Introduction

> [...] the way in which exchange rate movements pass through into import prices at the border and at the final consumer level is also critically important to understand the influence of external shocks on inflation. Consequently, understanding exchange rate pass-through into aggregate prices is vital for forecasting inflation and setting monetary policy. (Constâncio 2017)

The degree to which exchange rate changes are transmitted to import prices and subsequently to final consumer prices is commonly referred to as "exchange rate pass-through" (ERPT).[1] Assessing the degree of pass-through to import and domestic prices is particularly important for the conduct of monetary policy, as the exchange rate channel is one of the transmission channels through which monetary policy impulses are transferred to the real economy and affect price stability in the medium term (ECB 2011).

Exchange rate changes affect inflation in several ways. First, they are passed on directly to consumer prices via their impact on imported consumer goods. For example, following an exchange rate depreciation, imported final consumer goods become more expensive, pushing up overall consumer price inflation. The relevance of this channel, which connects import prices directly with consumer prices, mainly depends on the pricing decisions of foreign producers exporting to the euro area. Second, some imported goods are used as inputs into production, so an exchange rate depreciation translates into higher production costs, which feed through the different stages of domestic intermediate and final goods production and ultimately affect domestic consumer prices. The relevance of this channel, which links import prices directly to producer prices and indirectly to consumer prices, largely depends on the pricing behaviour of domestic firms. In particular, European firms might decide to pass on the increase in costs resulting from a euro depreciation, raising prices to keep mark-ups and profits constant, or they might leave prices unchanged and accept lower profits, thus damping the pass-through to final consumer prices. The distribution sector (local transportation costs and retailer market power) has an impact on both these channels. Third, exchange rate developments may also have an effect via their impact on the competitiveness of domestically produced goods on international markets ('expenditure switching' effects). An exchange rate depreciation makes domestically produced goods more competitive in terms of their price on world markets. This, in turn, leads to an increase in net exports, higher output growth and, via higher labour demand and higher wages, ultimately puts upward pressure on consumer prices.

The relationship between exchange rates and inflation is an actively researched area in economics. Seminal contributions were made by Campa & Goldberg (2005) and Burstein & Gopinath (2014). Goldberg & Knetter (1997) and Burstein & Gopinath (2014) provide excellent literature surveys.[2]. Indeed, the empirical literature covers different countries, time periods

[1] See ECB (2016).

[2] Goldberg & Knetter (1997) and Burstein & Gopinath (2014) focus mainly on linear models. Ha et al. (2019)

and empirical methodologies. With respect to the euro area countries, valuable insights about aggregate ERPT come from Campa et al. (2005), Campa & Goldberg (2005, 2010), Ben Cheikh & Rault (2016) and Özyurt (2016), who use mainly macro level data. Hahn (2003), Campa & González-Mínguez (2006), Campa & Goldberg (2008), Amiti et al. (2014), De Bandt & Razafindrabe (2014), Ben Cheikh & Rault (2017) and Osbat et al. (2019) use sectoral and micro level data. However, empirical estimates of ERPT to import and consumer prices are scarce, highly uncertain and heterogeneous across models, estimation samples and euro area countries. For policymakers this is a challenge, as it makes it significantly more difficult to anticipate the effect of currency market fluctuations on domestic inflation. For the euro area as a whole empirical estimates are very scarce, given the relatively short time history of the monetary union (EMU) as of 1999. Estimates for euro area ERPT to import and consumer prices summarised in ECB (2016) comprise an update of Hahn (2003), Comunale & Kunovac (2017) and two models used at the ECB. Özyurt (2016) and Osbat et al. (2019) are more recent studies providing ERPT estimates for import prices.

Another strand of literature focuses on the possibility that ERPT may be nonlinear across various dimensions. It may depend upon the level (or variability) of inflation, the state of the business cycle, the type of shock driving the exchange rate, or the sign and size of the exchange rate change.[3] Empirically Ben Cheikh & Louhichi (2016) for import prices and Gagnon & Ihrig (2004), Ben Cheikh (2012a), and Jašová et al. (2016) for consumer prices show that there is a link between ERPT, the inflation level and its variability. Ben Cheikh et al. (2018) show that ERPT can differ during expansions and recessions. Following up on the theoretical contribution by Corsetti et al. (2008), empirical evidence for shock-dependent ERPT is provided by Forbes et al. (2018) and Comunale & Kunovac (2017).

Our paper adds to the literature examining whether ERPT depends on the sign or size of the exchange rate change. Does it make any difference whether the exchange rate depreciates or appreciates, so-called *sign non-linearity*? Do larger exchange rate fluctuations entail more exchange rate pass-through, so-called *size non-linearity*? If so, what is the timing of these two non-linearities for import and consumer price inflation? Sign and/or size non-linearities for some euro area countries are analysed in Bussière (2013), Kiliç (2016), Razafindrabe (2017) and Brun-Aguerre et al. (2017) for import prices and in Delatte & López-Villavicencio (2012) and Ben Cheikh (2012b) for consumer prices. Although these studies find empirical evidence for sign and size non-linearities for a few specific euro area countries, evidence for the euro area countries is still relatively scarce and is not available for the euro area as a whole.[4]

This paper contributes to this strand of literature, providing estimates of ERPT to con-

focus on emerging market economies.

[3]For a thorough review of potential non-linearities in the relationship between exchange rates and inflation, see Delatte & López-Villavicencio (2012), Kiliç (2016), and Brun-Aguerre et al. (2017).

[4]Webber (2000) and Caselli & Roitman (2016) find non-linearities for import prices in emerging economies, Pollard & Coughlin (2004) for import prices in US industries and Przystupa & Wróbel (2011) for consumer prices in Poland.

sumer and import prices for all 19 euro area countries as well as the euro area as a whole, and investigating empirically whether ERPT is subject to sign and size non-linearities for import and consumer prices. We make use of the simplest and most flexible empirical methodology to estimate impulse responses, Jordà (2005) local projections (LP), and conduct our analysis country-by-country over 1997Q1 – 2019Q1. The LP methodology easily accommodates nonlinear specifications. To capture the presence of non-linearities in ERPT, and in particular to test whether the sign and the size of exchange rate changes affect the level of pass-through, we follow Bussière (2013) and Caselli & Roitman (2016) and introduce interaction terms in a standard linear regression model to estimate state-dependent impulse responses for consumer and import prices.

This paper bears several practical insights on ERPT in the euro area. First, ERPT to import prices after one year is larger if the quarter-on-quarter exchange rate change exceeds one standard deviation. This finding is present for total import prices (including internal euro area trade) and also for only extra-euro area import prices.[5] ERPT to consumer prices is small and only statistically significant after large exchange rate changes. That said, the size non-linearity is relatively short-lived – it unfolds during the first year after the exchange rate change, but then dissipates. Second, we find no evidence of sign non-linearity for ERPT into consumer or import prices in the euro area as a whole. We therefore conclude that the *size* rather than the *sign* of exchange rate movements significantly affects the level of ERPT in the euro area as a whole. Third, across individual euro area members, empirical evidence for sign and size non-linearity differs by non-linearity type and time horizon.

Studies that are relatively close to our approach include Delatte & López-Villavicencio (2012) and Brun-Aguerre et al. (2017), who use a non-linear Error Correction Model (ECM) to analyse the 'asymmetry' of exchange rate pass-through (i.e. *depreciation* versus *appreciation*) into consumer or import prices. Ben Cheikh (2012a) and Kiliç (2016) use a Smooth Transition Autoregressive (STAR) model and test for size non-linearity in ERPT into consumer or import prices. The LP econometric approach we use bypasses one important limitation of these so-called 'constant coefficient' models. Specifically, both ECM and STAR constrain the dynamic effect to increase or decrease monotonically over time, while LP estimates a separate coefficient for each time horizon. Discarding long-run restrictions and allowing as much inter-temporal flexibility as possible may establish more transparent stylised facts.

The rest of the paper is organised as follows. Section 2 provides technical details about LP estimates of the dynamic response of prices to exchange rate movements and briefly describes our dataset. Section 3 displays the empirical results and summarises key findings. Section 4 provides robustness checks using an alternative model specification and different samples. Finally, Section 5 concludes.

[5] ERPT into extra-euro area import prices is comparable with ERPT estimates for countries outside the EMU.

2 Methodology

Our analysis relies on a single-equation time series model similar to a dynamic Phillips curve. When controlling for domestic economic slack and external price pressures, this reduced-form equation measures the transmission of exchange rate changes into domestic prices over time. The main limitation of our approach is that it only estimates the elasticity of inflation to exchange rate movements. As a consequence, what we refer to as ERPT is a simple correlation between two variables, without any structural interpretation. We estimate the dynamic responses of inflation to exchange rate movements using local projections (LP), developed by Jordà (2005). The LP method provides a flexible framework without any explicit long-run restrictions on ERPT. Moreover, it easily accommodates nonlinear specifications. This section outlines the technical details about the implementation of the methodology and describes our dataset.

2.1 Local Projections

Suppose $t = 1, 2, ..., T$ measures the discrete time dimension of the data, while $h = 0, 1, ..., H < T$ denotes the projected horizon. Suppose further that p_t and e_t denote the natural log of the domestic price level and the nominal exchange rate, respectively. The $n \times 1$ vector of all other control variables is denoted $\mathbf{x}_t(h)$. The LP method generates estimates for each forecast horizon h by regressing the dependent variable at $t+h$ on the available information set at time t.[6] In our case, the linear LP of the cumulative rate of domestic price inflation is obtained by estimating H different regressions by ordinary least squares (OLS):

$$p_{t+h} - p_{t-1} = \alpha(h) + \phi(h)\Delta e_t + \sum_{i=0}^{q} \mathbf{x}'_{t-i}(h)\boldsymbol{\gamma}_i(h) + \sigma(h)u_{t+h}(h), \tag{2.1}$$

where $u_{t+h}(h) \sim N(0, 1)$ and $\sigma(h) > 0$ for all h. An impulse response (IR) can be defined as the difference between two forecasts. Therefore, an LP estimate of the impulse response, $\text{IR}_{h,t}$, of the cumulative inflation rate at horizon h to a change in the exchange rate at time t can be traced out by plotting $\phi(h)$ for $h = 0, 1, ..., H$, since

$$\text{IR}_{h,t} = \mathbb{E}_t[(p_{t+h} - p_{t-1})|\Delta e_t = 0.01] - \mathbb{E}_t[(p_{t+h} - p_{t-1})|\Delta e_t = 0] = \phi(h). \tag{2.2}$$

One of the main advantages of the above dynamic formulation is that the dependent variable is the cumulative rate of inflation over a given period of time. This implies that, for each horizon h, the statistical significance of ERPT can be assessed by standard inference on parameter $\phi(h)$. For this purpose, we use the Newey-West correction for heteroscedasticity and serial correlation.

The vector of control variables, $\mathbf{x}_t(h)$, includes up to q lags of inflation and of the first-differenced exchange rate in order to account for possible serial dependence. We also introduce

[6] Jordà (2005) denotes the collection of h regressions in (2.1) as *local projections*, a term evoking nonparametric methods.

different measures of domestic economic slack, denoted y_t, which reflect the state of aggregate demand and supply at a given point in time. In order to capture the source of external price pressure, we incorporate a weighted average of export price inflation in main trading partners of the euro area. The latter is denoted $\Delta s_t = s_t - s_{t-1}$. Finally, our dynamic specification incorporates the previous horizon residuals, $u_{t+h-1}(h-1)$, for all $h > 0$. Formally, the vector of control variables can be written:

$$\mathbf{x}_{t-i}(h) = \begin{cases} [\Delta p_{t-1}, \mathbf{0}_T, y_t, \Delta s_t, \mathbf{0}_T]' & \text{if } i = 0 \text{ and } h = 0, \\ [\Delta p_{t-i}, \Delta e_{t-i}, y_{t-i}, \Delta s_{t-i}, \mathbf{0}_T]' & \text{if } 1 < i \leq q \text{ and } h = 0, \\ [\Delta p_{t-1}, \mathbf{0}_T, y_t, \Delta s_t, u_{t+h-1}(h-1)]' & \text{if } i = 0 \text{ and } 0 < h \leq H, \\ [\Delta p_{t-i}, \Delta e_{t-i}, y_{t-i}, \Delta s_{t-i}, u_{t+h-1}(h-1)]' & \text{otherwise,} \end{cases} \tag{2.3}$$

where the zero vector $\mathbf{0}_T$ spans the entire sample of size T.

Augmenting LPs by recursively including the residuals of the $h-1$ LP horizon as regressors in the h horizon LP comes from the conjecture originally postulated by Jordà (2005), p. 166. This was developed explicitly by Teulings & Zubanov (2014) and Carrière-Swallow et al. (2016). On the one hand, the LP method is robust to a variety of model misspecifications, because a new set of coefficients is estimated for each horizon instead of relying on a restricted law of motion that uses the same set of coefficients for all horizons.[7] It therefore does not constrain the dynamic response of inflation to the exchange rate to be monotonically increasing or decreasing over time.[8] On the other hand, the LP method projects the cumulative inflation rate into the future while conditioning on regressors up to period t. This property is particularly desirable when conducting a counter-factual policy analysis. At longer horizons the LP estimator becomes increasingly inefficient and more susceptible to model misspecification errors. Including residuals from shorter-horizon regressions is therefore an effective way to expand the information set. We use the expression Augmented Local Projections (ALP) to refer to LPs including shorter-horizon residuals. The information set for the ALP is broader than for the LP, since LP use all the information available up to date t, while ALPs also incorporate residuals up to date $t+h-1$ for all $h > 0$. If the model depicted in equation (2.1) is correctly specified, then in principle both LPs and ALPs return an unbiased estimate of $\phi(h)$. However, the ALP estimator is generally characterised by a smaller OLS standard error, since it relies on additional information.

To capture possible non-linearities in ERPT, parameter $\phi(h)$ in equation (2.1) could be conditioned on different states associated with the exchange rate series. To test whether the sign and size of exchange rate changes affect the extent of pass-through, we introduce an indicator variable δ_t in equation (2.1), distinguishing the following states: (i) *depreciations* and *appreciations* of the exchange rate (*sign* non-linearity or *asymmetry*), in which case $\delta_t = 1|_{\Delta e_t \geq 0}$

[7] This comes at the cost of greater estimation uncertainty – especially when H is a non-negligible fraction of T.

[8] Alternative single-equation models, such as an Error Correction Model (ECM) used by Delatte & López-Villavicencio (2012) or Brun-Aguerre et al. (2017), resort to a single set of coefficients. The cumulative dynamic multipliers are then derived from a single set of parameter estimates.

(depreciation) and $\delta_t = 0|_{\Delta e_t<0}$ (appreciation); and (ii) *large* versus *small* exchange rate movements (*size* non-linearity), where $\delta_t = 1|_{|\Delta e_t|\geq\tau}$ (large exchange rate change in absolute terms) and $\delta_t = 1|_{|\Delta e_t|<\tau}$ (small exchange rate change in absolute terms). In the absence of a clear theoretical guideline, we set the threshold τ equal to one standard deviation of the first difference of the exchange rate series. The main advantage of this choice is that it picks up a sufficient number of observations in the sub-sample.[9] The non-linear ALP are obtained by estimating the following regression for each forecast horizon h:

$$p_{t+h} - p_{t-1} = \alpha(h) + \phi_0(h)[1-\delta_t]\Delta e_t + \phi_1(h)\delta_t\Delta e_t + \sum_{i=0}^{q} \mathbf{x}'_{t-i}(h)\boldsymbol{\gamma}_i(h) + \sigma(h)u_{t+h}(h), \quad (2.4)$$

where $\phi_0(h)$ measures ERPT at horizon h when the indicator variable δ_t is equal to zero and $\phi_1(h)$ measures ERPT when δ_t is equal to unity. Under the assumption that the error term is Gaussian, the null hypothesis of 'complete' pass-through ($\phi_0(h)$ or $\phi_1(h) = 1$) can be tested by a one-sided t-test. Similarly, the presence of asymmetry or size non-linearity can be determined using a Wald test of the hypothesis $\phi_0(h) = \phi_1(h)$ at any projected horizon h. In particular, if $\phi_0(h)$ and $\phi_1(h)$ are not significantly different, then ERPT is linear. This concludes the description of our empirical strategy and the discussion now turns to the description of the dataset.

2.2 Data

Our empirical analysis is based on a data set for each of the 19 euro area countries and the euro area as a whole during 1997Q1-2019Q1. All series are seasonally and working day adjusted (for some countries only seasonally adjusted), with the exception of the exchange rate. For consumer prices we use the country-specific Harmonised Index of Consumer Prices (HICP) available in the ECB Statistical Data Warehouse. Domestic economic slack is measured by country-specific output gap and the external price pressures are captured by a country-specific index of competitor export prices - both series retrieved from the Eurosystem Macroeconomic Projections Database.[10] The latter combines export price indices of the 31 main trade partners outside the euro area according to their share in euro area imports (also for each individual euro area country), thereby attaching more weight to external price changes emanating from the most important trade partners.[11]

[9] In our sample of 87 observations for the euro area we have 46% depreciation episodes and 29% large change episodes (see Table A1 in Annex A). Increasing the threshold would reduce the number of available observations for large changes and increase the uncertainty of the estimates.

[10] For the sake of robustness, we implemented the same methodology using an alternative measure of domestic economic slack, namely the unemployment gap (from the same source). The exercise is summarized in Section 4. Results are generally unchanged. We focus on the results based on the output gap, because it may be a better measure of slack as it also captures the total factor productivity gap, as well as participation and hours worked gaps.

[11] The indices for the euro area and countries are available in euros, therefore we deflate them by country-specific nominal effective exchange rate (based on the same weighting scheme) in order to obtain competitor price

The choice of the most appropriate exchange rate series is not straightforward, mostly because euro area countries trade a lot with each other. First, we are confronted with two measurement options: (i) the total-euro area nominal effective exchange rate (NEER) – a basket of currencies weighted by both intra- and extra-EA import shares; and (ii) extra-euro area NEER – a basket of currencies based exclusively on non-euro area trade partners. Since the total-euro area nominal effective exchange rate contains a substantial proportion that is constant, the most relevant NEER from the policy makers' perspective is based exclusively on trade partners outside euro area (i.e. extra-euro area). We therefore estimate ERPT into consumer prices using the extra-euro area NEER. Second, we have to choose between country import weights or export weights. We choose the import-weighted NEER as our measure, since we think that it is more appropriate when analysing import and consumer prices.

For ERPT to import prices, we are presented with two further options: (i) the total euro area import deflator for goods and services (national accounts concept) which also includes trade within the euro area (available from the ECB Statistical Data Warehouse); and (ii) extra-euro area import prices (available in the Eurosystem Macroeconomic projections database).[12] In principle, one would expect exchange rate changes to affect extra-euro area import prices more. However, total import prices could also capture spillovers from exchange rate changes via other euro area countries. In the main part of the paper we present ERPT estimates for total import prices and provide the results for extra-euro area import prices in Annex C. Estimates using total import prices are more comparable to those available in the literature. Estimates using extra-import prices provide a more appropriate comparison for countries which are not part of the monetary union.[13]

3 Results

We employ the general-to-specific approach to choose the most parsimonious model specification. The model selection procedure starts from an equally-numbered lag specification and moves towards fewer lags by inspecting the diagnostic statistics. We find that one lag for the dependent variable is generally sufficient to account for serial dependence according to the Durbin-Watson test statistic. Ultimately, our ALP estimates are based on a specification that incorporates the contemporaneous values and one lag for all control variables, except the dependent variable, which enters with just one lag. When $h = 0$ the Hausman test cannot reject the null hypothesis of no misspecification in all countries for both price indices. At longer horizons the Hausman test statistic does suggest that the model becomes increasingly misspecified, especially if the

movements in "national currency", i.e. excluding the impact of the exchange rate.

[12] Quarterly data are not available for Ireland, Greece, Slovenia, Cyprus, Luxembourg, and Malta, and have a poor quality for Lithuania.

[13] Some studies, such as Comunale & Kunovac (2017), estimate ERPT into total-EA import prices and then re-scale the outcome using the data on intra-euro area trade shares. However, for some countries we get very similar ERPT estimates for total and extra-euro area import prices, which suggests that intra-euro area price spillovers are not negligible (see Table C1 in Annex C).

residuals from the previous horizon are not included. However, the short sample size makes the extent of model misspecification difficult to assess with standard statistical tests. At horizons of eight quarters or more the estimates become particularly unstable and we exclude ALP for $h > 7$. The remainder of the paper reports the ERPT estimates for consumer and import prices and discusses the impulse response. More specifically, Subsection 3.1 presents the estimates from the linear model for each of the 19 euro area countries as well as for the euro area as a whole. Subsection 3.2 and Subsection 3.3 present evidence on sign and size non-linearity.

3.1 Linear exchange rate pass-through and its time profile

Table 1 presents the estimates of ERPT based on the linear model defined in equation (2.1). Below, we focus on the ALP estimates at the three horizons that have become customary in the related literature: on impact ($h = 0$), after one year ($h = 3$), and after two years ($h = 7$). We then test for three possible outcomes of interest, namely (i) no ERPT, (ii) incomplete ERPT and (iii) complete ERPT.

Table 1: Linear ERPT

	Import prices			Consumer prices		
	Impact	1 year	2 years	Impact	1 year	2 years
EA	0.20*	0.33*	0.15	0.02	0.04	0.04
DE	0.28*	0.54*	0.49*	0.05*	0.06*	0.09*
FR	0.20*	0.34*	0.29*	0.04*	0.03	0.04
IT	0.42*	0.63*	0.50*	0.03*	0.05*	0.07*
ES	0.24*	0.54*	0.47*	0.06*	0.09*	0.12*
NL	0.24*	0.38*	0.34*	0.02	0.05*	0.14*
BE	0.27*	0.24	0.22	0.08*	0.05	0.08*
AT	0.34*	0.45*	0.47*	0.05*	0.09*	0.13*
PT	0.31*	0.50*	0.37*	0.04	0.05	0.08*
FI	0.23*	0.35*	0.17	0.05*	0.08*	0.14*
GR	0.23*	0.16	0.37*	0.06*	0.09*	0.13*
IE	0.44*	0.30*	0.12*	0.03	0.06	0.07
LU	0.33*	0.47*	0.11	0.13*	0.13*	0.11
Countries joining the euro area after 2007						
SK	0.04	0.34*	0.36*	0.00	0.14*	0.11
LT	0.34	0.45	0.87*†	0.04	0.18*	0.23*
SI	0.30*	0.33*	0.34*	0.06*	-0.09	-0.06
LV	0.28*	0.46*	0.27	0.02	0.15	0.12
EE	0.11*	0.22*	0.14*	0.09*	0.17	0.17
CY	0.08*	0.14*	0.04	0.03	0.01	-0.05
MT	0.08	0.48*	0.36*	0.04*	0.09*	0.02

Note: The asterisk $*$ indicates that the coefficient is significantly different from zero; the dagger † indicates that it is not significantly different from unity; The level of significance is 5% in all cases.

For the euro area as a whole, we find that ERPT to import prices is 20% on impact. One year

after the exchange rate change, ERPT into import prices rises to 33%, remaining incomplete, but after two years it is no longer statistically significant (see top row of Table 1).[14] For consumer prices euro area estimates are very small, only around 2% at impact, and are not significant. This is at the lower range of estimates reported in ECB (2016).

The pattern for euro area ERPT to import prices is consistent with estimates for individual euro area countries. Although the tables report results for all euro area countries, the discussion will focus on those with longer data series. The ERPT estimates for countries that joined after 2007 should be treated cautiously as for most of the sample they had a different currency. For the original euro area member countries, results show that import prices react only partially to exchange rate changes on impact: the estimated ERPT ranges between 20% and 40% (top left-side panel of Table 1). After one year, the response increases for most countries and lies within the range 30-60% , with Italy displaying the largest coefficient (63%). After two years, ERPT declines in 9 out of 12 original member countries and in some cases is not statistically different from zero. However, second year estimates are subject to more uncertainty and the decline is not likely to be statistically significant. The null hypothesis of complete exchange rate pass-through is rejected at all considered horizons for all original euro area countries. This is not very surprising given that our measure of import prices also includes intra-euro area trade, which is mainly denominated in euros and only indirectly responds to exchange rate movements. To summarise, our estimates suggest that the ERPT into import prices follows a hump-shaped response over time in most euro area countries. In particular, there is only a partial pass-through on impact (between 20% and 40%), this rises after one year (reaching 30-60%), but then stabilises or slightly declines in the course of the second year. These results are partially at odds with the monotonically increasing response found with error-correction models, such as in Brun-Aguerre et al. (2017). In Section 4 we assess whether this evidence is robust to alternative model specifications and estimation samples.

For consumer prices results are quite different (see the right-hand side panel of Table 1). We find that the average response on impact is significant, but very small, with the only exceptions of non-significant estimates for Netherlands, Portugal and Ireland (see the first column on the right-hand side of Table 1). Eight out of 12 original members exhibit an increase in ERPT to consumer prices after one year. The most pronounced response on impact occurs in Luxembourg, where 13% of exchange rate movements are passed through to consumer prices, but for most other countries the impact is below 1%. Over a two-year horizon, ERPT is highest in the Netherlands and Finland (14%). However, pass-through remains relatively limited compared to that on import prices. Overall, our estimates suggest that ERPT to consumer prices differs substantially across euro area countries and that the impact on headline inflation is small. This is broadly in line with the empirical literature which found limited (and clearly incomplete) ERPT into consumer prices in many advanced economies, see Campa & Goldberg (2010), Ben Cheikh

[14] Özyurt (2016) finds much larger effect using extra-euro area prices instead of total import prices. Our results using extra-euro area import prices are broadly similar to Özyurt (2016) (see Annex C).

(2012b), Delatte & López-Villavicencio (2012) among others.

What might explain the hump-shaped response of euro area import prices to exchange rate changes? One possibility is nominal rigidity from setting import prices in local currency. In the pricing-to-market paradigm originally proposed by Betts & Devereux (2000) and Devereux & Engel (2003), it takes time for prices to adjust in response to exchange rate changes, since international product markets are segmented in the short run. However, over time the global forces of competitiveness and arbitrage eliminate any cross-border gap in prices. Local currency pricing contributes to explain why import prices fail to adjust fully on impact. Our estimates suggest that it takes approximately one year for ERPT to import prices, which could reflect the renegotiation of one-year contracts. It could also reflect hedging activities by firms. However, for longer horizons the influence of exchange rate changes may be blurred by other factors that are hard to identify in a reduced-form analysis like ours, which requires some caution when interpreting the results.

To what extent are our low and statistically insignificant estimates for longer horizons due to the increasing severity of model misspecification? In our ALP setting, each regression includes the residuals from inflation projections over shorter horizons. This may explain why exchange rate movements in the distant past no longer have a significant effect on inflation. However, whether we include shorter-horizon residuals has little effect on our point estimates. When we excluded the residuals, as in Jordà (2005), the results were qualitatively and quantitatively similar, except that the standard errors of the OLS estimates were larger for LP than ALP, as expected.[15]

In summary, our estimates of linear ERPT in the euro area and its member countries suggest that (i) ERPT into import prices is incomplete and follows a slightly hump-shaped pattern, with partial pass-through on impact, increasing after one year and slightly declining after two; (ii) ERPT to consumer prices increases steadily over two years, but remains limited at all horizons, especially compared to results for import prices.

3.2 Non-linear exchange rate pass-through: sign non-linearity

Does it make a difference whether the euro depreciates or appreciates? In other words, does the response of prices depend on the *sign* of the exchange rate change? Table 2 presents the estimates of ERPT from equation (2.4), where the dummy variable δ_t splits the sample into euro depreciations and appreciations. In this setting, we are able to test whether the coefficients for depreciations and appreciations are significantly different which would represent evidence of a sign non-linearity in ERPT.

In the euro area as a whole, the difference between ERPT following euro depreciations and appreciations is not statistically significant for import or consumer prices at all horizons. However, our estimates suggest that euro area import prices react significantly to appreciations

[15] The complete set of estimation results is available upon request.

Table 2: ERPT: Sign Non-linearity

	Import Prices						Consumer Prices					
	Euro Depreciation			Euro Appreciation			Euro Depreciation			Euro Appreciation		
	Impact	1 Year	2 Years	Impact	1 Year	2 Years	Impact	1 Year	2 Years	Impact	1 Year	2 Years
EA	0.11	0.04	0.04	0.26*	0.55*	0.21	0.04	0.02	0.03	0.01	0.06	0.05
DE	**0.20***	**0.23**	0.47*	**0.37***	**0.83***†	0.50	0.05*	**0.00**	0.07	0.04*	**0.12***	0.11
FR	**0.14***	**0.06**	0.31	**0.28***	**0.65***	0.26	0.05*	0.01	0.09	0.03	0.05	0.00
IT	0.41*	0.42	0.82*†	0.43*	0.84*†	0.16	0.03*	0.03	0.12*	0.04*	0.08*	0.02
ES	0.15	0.25	0.60*†	0.33*	0.85*†	0.34	0.04	**-0.03**	0.10	0.07*	**0.23***	0.15*
NL	0.15*	0.21	0.65*†	0.33*	0.55*	0.01	0.03	0.04	0.13*	0.00	0.06	0.15*
BE	0.23*	0.24	**0.69***†	0.30*	0.24	**-0.32**	0.08*	0.05	**0.20***	0.08*	0.04	**-0.08**
AT	0.32*	0.47*	0.64*	0.36*	0.43*	0.26	0.03	0.06	0.16*	0.07*	0.12*	0.09
PT	0.24*	**0.12**	0.43	0.39*	**0.97***†	0.35	0.03	**-0.06**	0.03	0.05	**0.18***	0.16
FI	0.18*	0.16	0.48*	0.26*	0.52*	-0.11	0.07*	0.10	0.11	0.03	0.06	0.16*
GR	0.24	-0.15	0.30	0.22	0.45*	0.43	**0.13***	0.17*	0.33*	**0.00**	0.02	-0.07
IE	0.50*	0.48*	0.22	0.36*	0.09	0.00	0.03	0.07	0.12	0.03	0.05	0.02
LU	0.32*	0.46*	**0.38***	0.34*	0.49*	**-0.23**	0.13*	0.15*	**0.31***	0.12*	0.10	**-0.12**
Countries joining the euro area after 2007												
SK	-0.02	0.36*	0.31	0.08	0.32*	0.39	0.00	0.15	-0.01	0.01	0.13	0.20
LT	0.38	0.04	1.25*†	0.32	0.76*†	0.61	0.10	0.17	-0.05	0.00	0.19	0.46*
SI	0.29*	0.40*	0.71†	0.30*	0.23	-0.19	0.07	-0.12	0.04	0.04	-0.05	-0.19
LV	0.26	**-0.02**	-0.33	0.29*	**0.71***†	0.61*†	0.09	0.01	**-0.39**	-0.01	0.23*	**0.42***
EE	0.13	0.09	0.21	0.10	0.31*	0.08	0.16*	0.24	0.28	0.03	0.11	0.06
CY	0.08*	0.09	**0.22***	0.08*	0.18*	**-0.17**	0.04	0.03	**0.12**	0.01	-0.01	**-0.24**
MT	-0.05	0.47*	0.41*	0.22	0.50*	0.29*	**0.11***	**0.17***	0.09	**-0.02**	**-0.01**	-0.06

Note: The asterisk ∗ indicates that the coefficient is significantly different from zero; the dagger † indicates that it is not significantly different from unity; bold indicates statistically significant differences between euro depreciations and appreciations using a Wald test with a single linear restriction. The level of significance is 5% in all cases.

but not depreciations (uncertainty bands are wide). Following appreciations, ERPT is 55% after one year but becomes statistically insignificant after two years. For consumer prices, coefficients for appreciations and depreciations remain insignificant, as in the linear case.[16]

Estimates suggest sign non-linearity in ERPT to import prices for seven out of 12 original euro area member countries (left-hand side of Table 2). ERPT is significantly greater following euro appreciations in Germany, France, Spain, Ireland and Portugal.[17] However, the pattern of sign non-linearity varies somewhat across countries and is generally rather short-lived. Two years after the exchange rate change, the sign non-linearity is no longer present in the larger countries. For Belgium and Luxembourg the response to depreciations is larger than to appreciations. This effect, however, shows up at the two-year horizon.

For consumer prices the evidence for sign non-linearity is also mixed, but for five countries the pattern is consistent with that found for import prices (right-hand side of Table 2). For Germany, Spain and Portugal appreciations are passed on more than depreciations. For Belgium and Luxembourg the opposite is true. The time profile varies across countries, but the non-linearity

[16]For the sake of robustness, we estimated asymmetric ERPT excluding residuals, as in Subsection 3.1. The results are available upon request.

[17]For Spain the sign non-linearity is present for the first and second quarter and for Ireland for the first quarter - horizons not shown in the Table 2.

for consumer prices tends to appear at longer horizons than for import prices. For France and Ireland the non-linearity observed for import prices is no longer present for consumer prices, suggesting that the domestic pricing chain absorbs the non-linearity present at the border. The only country with sign non-linearity for consumer prices but not for import prices is Greece. For this country, ERPT to consumer prices seems to be larger following depreciations than appreciations at all horizons.

To summarise, (i) in the euro area as a whole, ERPT into consumer and import prices is not statistically different following euro depreciations and appreciations; (ii) ERPT into euro area import prices is only statistically significant on impact during an appreciation and up to one year after; (iii) in Germany, France and Spain, ERPT into import prices is statistically larger for appreciations than for depreciations, but the asymmetry vanishes after two years.[18] This suggests that neglecting the presence of sign non-linearities may lead one to underestimate the impact of exchange rate appreciations.

3.3 Non-linear exchange rate pass-through: size non-linearity

What if the exchange rate change is relatively large from a historical perspective – does it entail a disproportionately greater exchange rate pass-through? Table 3 presents the ERPT estimates from equation (2.4), where the dummy variable δ_t splits the sample into relatively large and small quarterly changes, with the threshold set at one standard deviation of quarterly changes in NEER. This corresponds to 2.3% for the euro area and around 3% in individual euro area countries (see Table A1 in Appendix A). Once again, we test for ERPT completeness and we investigate whether the response is significantly different following large and small changes to the NEER (i.e. $\mathcal{H}_0 : \phi_0(h) = \phi_1(h)$).

For the euro area as a whole, our findings suggest that large exchange rate changes lead to greater ERPT into both import and consumer prices, but only within the first year (for h=1 to 4 horizons). Our results show that after one year 49% of large exchange rate movements are transmitted to import prices, while small movements have little effect on impact and are not statistically significant after one year. ERPT into import prices is incomplete and import prices appear to respond more when the euro area is hit by large exchange rate shocks, which is consistent with the menu costs theory. Finally, the slightly hump-shaped profile of ERPT into import prices only appears for large exchange rate movements. For consumer prices, large exchange rate changes generate a cumulative response of headline inflation equal to 7% after one year, but small exchange rate changes have little impact. We conclude that the size of exchange rate movements significantly affects the degree of ERPT into euro area consumer and import prices.

Evidence of size non-linearity for import prices appears in six out of 12 original euro area countries (see the left-hand side of Table 3). For France, Spain, the Netherlands and Belgium, we

[18] Brun-Aguerre et al. (2017) find larger long-run impact of depreciations only for Greece, but not for other euro area economies. They start their sample in 1980, including the Exchange Rate Mechanism crisis in 1992.

Table 3: ERPT: Size Non-linearity

	Import Prices						Consumer Prices					
	Large Euro Change			Small Euro Change			Large Euro Change			Small Euro Change		
	Impact	1 Year	2 Years	Impact	1 Year	2 Years	Impact	1 Year	2 Years	Impact	1 Year	2 Years
EA	0.23*	**0.49***	0.18	0.12*	**-0.15**	0.11	0.03*	**0.08***	0.06	0.00	**-0.06**	0.00
DE	0.29*	0.61*	0.53*	0.26*	0.32*	0.30	0.04*	0.07*	0.09*	0.07*	0.05	0.06
FR	**0.18***	**0.40***	**0.39***	**0.29***	**0.17**	**0.00**	0.04*	0.04	0.05	0.06*	0.01	0.01
IT	0.41*	0.70*	0.62*†	0.46*	0.49*	0.30	0.03*	0.06*	0.09*	0.05*	0.04	0.04
ES	**0.19***	0.63*	**0.67***	**0.36***	0.32	**-0.10**	**0.04***	0.09*	0.11*	**0.09***	0.09*	0.17*
NL	0.22*	**0.49***	**0.63***	0.28*	**0.10**	**-0.43***	**0.00**	**0.03**	0.14*	**0.06***	**0.12***	0.16*
BE	0.26*	**0.37***	0.27*	0.27*	**-0.02**	0.11	0.08*	0.06	0.10*	0.09*	0.02	0.03
AT	0.32*	0.47*	0.49*	0.39*	0.43*	0.43*	0.04*	0.09*	0.14*	0.06*	0.08	0.12
PT	0.27*	0.59*	0.46*	0.41*	0.27	0.14	0.04	0.06	0.07	0.04	0.05	0.09
FI	0.26*	0.36*	**0.02**	0.14	0.35*	**0.54***	**0.07***	0.11*	0.16*	**-0.01**	0.00	0.06
GR	0.20*	0.14	0.30*	0.35*	0.23	0.62*†	0.07*	0.10*	0.13*	0.04	0.07	0.15
IE	0.45*	0.39*	0.21*	0.39*	0.10	-0.09	0.04	0.09	**0.14**	0.01	0.01	**-0.06**
LU	**0.26***	0.44*	0.06	**0.49***	0.54*	0.26	0.12*	0.15*	0.11	0.13*	0.09	0.11
Countries joining the euro area after 2007												
SK	0.02	0.33*	0.33*	0.10	0.38	0.49	**-0.02**	0.08	**0.01**	**0.12***	0.38*	**0.62***
LT	0.35	0.45	**0.66***†	0.34	0.46	**1.78***†	0.06	0.21*	0.21	-0.03	0.08	0.30
SI	0.27*	0.29	0.32	0.36*	0.39*	0.38	0.05	-0.11	-0.14	0.08*	-0.04	0.10
LV	0.25*	0.40	0.28	0.39*	0.63*	0.24	0.01	0.11	0.10	0.05	0.28*	0.20
EE	0.14*	0.27*	0.14	0.03	0.08	0.16	0.11*	0.23*	0.22*	0.02	-0.04	0.02
CY	0.08*	0.17*	0.00	0.09*	0.05	0.13	0.02	0.02	-0.05	0.05	-0.01	-0.06
MT	0.02	0.50*	0.42*	0.23	0.48*	0.30*	0.03	0.05	0.03	0.08*	0.15*	0.03

Note: The asterisk ∗ indicates that the coefficient is significantly different from zero; the dagger † indicates that it is not significantly different from unity; bold indicates statistically significant differences between large and small exchange rate changes using a Wald test with a single linear restriction. The level of significance is 5% in all cases.

find that large exchange rate changes have more impact than small changes. For most countries the size non-linearity is present within the first year. In contrast, for two smaller member countries, namely Finland and Luxembourg, small changes have proportionally more impact.

For consumer prices, the size non-linearity only appears for four original euro area members: Spain, the Netherlands, Finland and Ireland (right-hand side of Table 3). For Spain and the Netherlands, ERPT to consumer prices is proportionally higher for small changes than for large changes, whereas for Finland the opposite is true. The non-linearity appears during the first year in some countries, while in others it only appears after two years.

By and large, for both import and consumer prices we find that large changes are more likely to lead to statistically significant ERPT than small changes (10 countries versus 5 for import prices and 7 versus 2 for consumer prices). The size non-linearity for import and consumer prices is in the opposite direction for Spain, the Netherlands and Finland. A number of factors may explain this finding. First, final consumer goods are only a fraction of total imports of goods and services for any country and it may be that size non-linearity for imports of commodities and intermediate inputs dominates that of consumer goods. Second, the transmission mechanism from import prices to consumer prices is very complex and involves a number of domestic sectors - transportation and storage, producers and retailers. The final consumer price encompasses

intertwined effects of market power and price setting behaviour by all these sectors (for discussion of these impacts see for example Burstein & Gopinath (2014)).

In summary, (i) for the euro area as a whole, consumer and import prices respond more to large exchange rate changes, but non-linearity dissipates after the first year; (ii) ERPT into import prices remains incomplete and follows a hump-shaped pattern, but only for large exchange rate movements; and (iii) at the country level, the size non-linearity differs – in some countries, prices absorb a greater proportion of relatively small exchange rate changes, while in others prices only react significantly to large exchange rate changes.

4 Robustness

This section evaluates the robustness of our results along two dimensions: model specification and parameter stability. In Subsection 4.1 we test the robustness of our model specification by using the unemployment gap instead of the output gap to measure economic slack. In Subsection 4.2 we assess the sensitivity of results to changes in the estimation sample.

4.1 Are ERPT estimates affected by the measure of economic slack?

The vector of explanatory variables $\mathbf{x}_t$ in equation 2.3 includes a variable y_t to control for domestic demand and supply factors. This is standard practice in the ERPT literature, although the choice of the variable differs across studies. For example, Jašová et al. (2016) use the domestic output gap while Özyurt (2016) uses the unit labour cost. Our benchmark specification includes the output gap, which in principle captures a broader measure of slack than the unemployment gap. To assess whether our results are robust to alternative measures of economic slack, we re-estimate the linear and non-linear model in equations (2.1) and (2.4), replacing the output gap with the unemployment gap. As described in Section 3, we use the general-to-specific approach to select a parsimonious model that incorporates the contemporaneous values and one lag for all control variables, with the exception of the dependent variable, which enters with just one lag. The results of this exercise are shown in Appendix B, Tables B1 to B3.

The left-hand side of Table B1 indicates that for import prices ERPT estimates are rather similar with either output gap or the unemployment gap. Only for some cases (euro area, Belgium and Luxembourg) does the unemployment gap lead to larger estimates than those in Table 1, especially for one and two-year horizons. Qualitatively, the profile of import price responses to exchange rate movements remain largely unchanged.

For consumer prices, ERPT estimates with the linear model are also rather robust to the choice of slack variable (first column on the right-hand side of Table B1), although less than for import prices. Discrepancies in the magnitude and in the statistical significance of the estimated coefficients appear one year after the exchange rate shock, especially for Belgium, Austria, Portugal, Greece, Ireland and Luxembourg. For most of these countries, with the exception of Greece, ERPT estimates using the unemployment gap are larger. For Greece,

ERPT is lower and becomes insignificant two years after the exchange rate change. From a qualitative point of view, however, ERPT into consumer prices reported in Table 1 is consistent with Table B1. The somewhat higher ERPT to consumer prices with the unemployment gap could mean that consumer prices are more closely linked to the state of the labour market, while import prices are more closely linked to the overall state of the economy. However, comparing adjusted R-squared statistics over the estimated horizon, does not support this hypothesis. Fit is not systematically higher for specifications with the unemployment gap (see Table 4). We leave further analysis for future work.

Table 4: Linear ERPT: Adjusted R-squared (average over 8 horizons)

														Countries joining the euro area after 2007						
	EA	DE	FR	IT	ES	NL	BE	AT	PT	FI	GR	IE	LU	SK	LT	SI	LV	EE	CY	MT
Import prices																				
output gap	0.58	0.70	0.63	0.63	0.59	0.56	0.63	0.66	0.61	0.58	0.54	0.55	0.59	0.51	0.45	0.58	0.51	0.56	0.55	0.57
unemployment gap	0.53	0.62	0.61	0.61	0.59	0.55	0.59	0.61	0.61	0.57	0.55	0.53	0.48	0.46	0.44	0.60	0.50	0.55	0.63	0.58
Consumer prices																				
output gap	0.58	0.55	0.60	0.71	0.69	0.58	0.63	0.57	0.61	0.46	0.71	0.71	0.59	0.42	0.66	0.53	0.67	0.58	0.54	0.42
unemployment gap	0.63	0.54	0.61	0.66	0.68	0.52	0.57	0.55	0.60	0.55	0.77	0.60	0.62	0.52	0.62	0.52	0.62	0.53	0.70	0.47

Turning to the non-linear equation 2.4, Table B2 confirms that the sign of the exchange rate change affects ERPT to consumer and import prices only in a few euro area countries. Qualitatively the estimates are similar for most countries. The sign non-linearity for import prices is confirmed for Germany, France, Spain and Portugal. For Belgium and Luxembourg uncertainty at the two-year horizon is higher with the unemployment gap and the Wald test fails to reject at the 5% significance level the difference in coefficients for appreciations and depreciations. The results for the euro area, Austria and Greece now suggest a sign non-linearity, but this reflects narrower confidence bands rather than qualitatively different coefficient estimates. For consumer prices, results are also broadly similar to those with the output gap. The sign non-linearity is confirmed for Spain, Portugal, Greece and Luxembourg. Estimates are more uncertain for Germany, but more precise for Austria.

Table B3 presents estimates for the size non-linearity using unemployment gap as economic slack control variable. For import prices, the size non-linearity in generally confirmed. For Luxembourg results are more uncertain with the unemployment gap and linearity cannot be rejected. For Italy, the Wald test now suggests statistically significant size non-linearity. For consumer prices, size non-linearity is confirmed for the euro area, Spain, the Netherlands, Finland and Ireland, also appearing for Belgium.

Overall, our analysis suggests that (i) neither measure of economic slack can claim to uniformly provide better fit to the data. In other words, the choice of economic slack proxy should depend on the inflation measure and the country under scrutiny; (ii) uncertainty remains large, especially at the two-year horizon; (iii) despite some discrepancies, the main conclusions drawn in Section 3 are generally confirmed by this robustness check.

Figure 1: Euro Area Linear ERPT : Import Prices

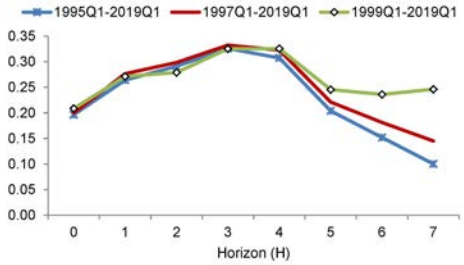
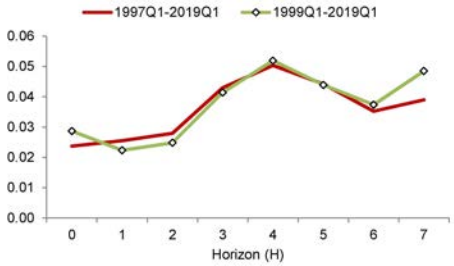


Figure 2: Euro Area Linear ERPT: Consumer Prices



4.2 Are ERPT estimates subject to parameter instability?

This subsection assesses the stability of the linear and nonlinear ALP models through sub-sample analysis. We estimate our benchmark specification of equations (2.1) and (2.4) on samples featuring the same end date, 2019Q1, and different starting points: 1995Q1 (only for import prices), 1997Q1 (start of the seasonally adjusted data for consumer prices) and 1999Q1 (start of the euro area). We then assess the robustness of the hump-shaped response found previously and, more generally, evaluate whether our results depend on the choice of estimation sample. For the sake of brevity, we report only the linear results for the euro area in Figures 1 and 2.[19]

Whether the sample starts in 1995 or in 1997, the responses of cumulative inflation to a one-off exchange rate change practically overlap over the considered time horizon and feature a clear hump-shape, as in Section 3. However, if the sample starts in 1999, the hump shape in the inflation response is less pronounced and does not fade at the two years horizon. Comparing estimates starting in 1995 and in 1999 suggests that the ERPT impact has become somewhat more persistent (in Figure 1 the second year estimates are higher with the sample starting in 1999). For consumer prices, estimates are similar for both starting periods (see Figure 2). This suggests that ERPT point estimates are sensitive to the estimation sample, especially for longer time horizons, suggesting that reduced form results should be interpreted cautiously, especially given the short estimation sample available.

Overall, the evidence of size non-linearity for import and consumer prices in the euro area holds across all samples examined. Also at the country level, the evidence of country-specific non-linearities is rather robust: our ERPT estimates are broadly similar upon impact, with slight differences at longer horizon. (see Figures D1 and D2 and Table D1 in Annex D).

[19]The complete set of results for original euro area members is available upon request.

5 Conclusion

The literature on exchange rate pass-through provides theoretical underpinnings and empirical evidence for non-linearities. Those may reflect downward rigidities in prices, binding capacity constraints, market share strategies, menu costs, the choice of invoicing currency, the state of the business cycle or the level and variability of inflation. The empirical literature on non-linear ERPT is relatively scarce, especially for the euro area. This paper examines possible non-linearities in ERPT to consumer and import prices in all 19 euro area countries as well as the euro area as a whole.

The empirical exercise is conducted with the country-specific harmonized index of consumer prices and the aggregate deflator for goods and services imports, using quarterly data from 1997Q1 to 2019Q1. The analysis extends a standard single-equation linear framework with additional interaction terms to account for possible non-linearities. Local projection techniques provide state-dependent impulse response functions. Due to the relatively short estimation sample available and to the intrinsic limitations of the LP estimator, estimates for longer horizons are subject to wide uncertainty.

Evidence for the euro area as a whole suggests that ERPT to import prices is greater when exchange rate movements are larger. For consumer prices, ERPT is not significant, except when exchange rate changes are large. Specifically, if the quarter-on-quarter change in the nominal effective exchange rate exceeds one standard deviation, then exchange rate pass-through into euro area headline inflation averages only to 8%. The size non-linearity is relatively short-lived, disappearing at the two-year horizon. We find no evidence of sign non-linearity (asymmetric exchange rate transmission to headline or import price inflation). We therefore conclude that the *size* rather than the *sign* of exchange rate movements significantly affects the level of ERPT in the euro area as a whole.

For individual euro area countries, our estimates of ERPT to import prices suggest that they respond only partially on impact, possibly because our measure of import prices includes intra-euro area trade. For consumer prices, ERPT differs substantially across countries, but the impact on headline inflation is generally very small. For import prices, in some large euro area countries ERPT is significantly higher following euro appreciations than depreciations, but only at shorter horizons. Only a handful of euro area countries display significant evidence of sign non-linearity in ERPT to consumer prices, but the direction and the time profile of the asymmetry vary from country to country. For size non-linearity, the response of prices to large and small exchange rate movements differs across inflation measures and countries: in some countries, prices respond more to relatively small exchange rate changes, while in others prices only react significantly to large exchange rate changes.

Our robustness checks provide additional insights. First, for both consumer and import price inflation our results appear to be qualitatively robust to the choice of proxy for economic slack. However, neither of the two measures considered can uniformly provide the better fit

to the data, and the uncertainty surrounding the estimates remains large. In other words, the measure of economic slack should depend on the country and on the inflation measure under scrutiny. Second, the hump-shaped profile of our import price ERPT estimates is sensitive to the estimation sample. Third, although ERPT estimates appear to be subject to some instability, we find robust evidence of non-linearities in ERPT in the euro area and its member countries.

References

Amiti, M., Itskhoki, O. & Konings, J. (2014), 'Importers, Exporters, and Exchange Rate Disconnect', *American Economic Review* **104**(7), 1942–78.

Ben Cheikh, N. (2012a), 'Non-linearities in Exchange Rate Pass-Through: Evidence from Smooth Transition Models', *Economics Bulletin* **32**(3), 2530–2545.

Ben Cheikh, N. (2012b), 'Asymmetric exchange rate pass-through in the Euro area: New evidence from smooth transition models', *Economics - The Open-Access, Open-Assessment E-Journal* **6**, 1–28.

Ben Cheikh, N. & Louhichi, W. (2016), 'Revisiting the role of inflation environment in exchange rate pass-through: A panel threshold approach', *Economic Modelling* **52**, 233–238.

Ben Cheikh, N. & Rault, C. (2016), 'Recent Estimates of Exchange Rate Pass-Through to Import Prices in the Euro Area', *Review of World Economics* **152**(1), 69–105.

Ben Cheikh, N. & Rault, C. (2017), 'Investigating first-stage exchange rate pass-through: Sectoral and macro evidence from euro area countries', *The World Economy* **40**(12), 2611–2638.

Ben Cheikh, N., Zaied, Y. B., Bouzgarrou, H. & Nguyen, P. (2018), 'Nonlinear Exchange Rate Pass-Through: Does Business Cycle Matter?', *Journal of Economic Integration* **33**(2), 1234–1260.

Betts, C. & Devereux, M. (2000), 'Exchange Rate Dynamics in a Model of Pricing-to-Market', *Journal of International Economics* **50**(1), 215–244.

Brun-Aguerre, R., Fuertes, A.-M. & Greenwood-Nimmo, M. (2017), 'Heads I win; Tails You Lose: Asymmetry in Exchange Rate Pass-Through into Import Prices', *Journal of the Royal Statistical Society: Series A (Statistics in Society)* **180**(2), 587–612.

Burstein, A. & Gopinath, G. (2014), Chapter 7 - International Prices and Exchange Rates, *in* G. Gopinath, E. Helpman & K. Rogoff, eds, 'Handbook of International Economics', Vol. 4 of *Handbook of International Economics*, Elsevier, pp. 391 – 451.

Bussière, M. (2013), 'Exchange Rate Pass-through to Trade Prices: The Role of Nonlinearities and Asymmetries', *Oxford Bulletin of Economics and Statistics* **75**(5), 731–758.

Campa, J. & Goldberg, L. (2010), 'The Sensitivity of the CPI to Exchange Rates: Distribution Margins, Imported Inputs, and Trade Exposure', *The Review of Economics and Statistics* **92**(2), 392–407.

Campa, J. & Goldberg, L. S. (2005), 'Exchange Rate Pass-Through into Import Prices', *The Review of Economics and Statistics* **87**(4), 679–690.

Campa, J. & Goldberg, L. S. (2008), Pass-Through of Exchange Rates to Consumption Prices: What Has Changed and Why?, *in* 'International Financial Issues in the Pacific Rim: Global Imbalances, Financial Liberalization, and Exchange Rate Policy (NBER-EASE Volume 17)', NBER Chapters, National Bureau of Economic Research, Inc, pp. 139–176.

Campa, J., Goldberg, L. S. & González-Mínguez, J. M. (2005), Exchange-Rate Pass-Through to Import Prices in the Euro Area, Working Paper 11632, National Bureau of Economic Research.

Campa, J. & González-Mínguez, J. M. (2006), 'Differences in exchange rate pass-through in the euro area', *European Economic Review* **50**, 121–145.

Carrière-Swallow, Y., Gruss, B., Magud, N. E. & Valencia, F. (2016), Monetary Policy Credibility and Exchange Rate Pass-Through, IMF Working Paper WP/16/240, International Monetary Fund.

Caselli, F. G. & Roitman, A. (2016), Non-Linear Exchange Rate Pass-Through in Emerging Markets, IMF Working Papers 16/1, International Monetary Fund.

Comunale, M. & Kunovac, D. (2017), Exchange Rate Pass-Through in the Euro Area, Working Paper Series 2003, European Central Bank.

Constâncio, V. (2017), 'Understanding and overcoming low inflation', Remarks at the Conference on 'Understanding inflation: lessons from the past, lessons for the future?', European Central Bank, Frankfurt am Main.

Corsetti, G., Dedola, L. & Leduc, S. (2008), 'High Exchange-Rate Volatility and Low Pass-Through', *Journal of Monetary Economics* **55**(6), 1113 – 1128.

De Bandt, O. & Razafindrabe, T. (2014), 'Exchange Rate Pass-Through to Import Prices in the Euro-Area: A Multi-Currency Investigation', *International Economics* **138**, 63 – 77.

Delatte, A.-L. & López-Villavicencio, A. (2012), 'Asymmetric Exchange Rate Pass-Through: Evidence from Major Countries', *Journal of Macroeconomics* **34**(3), 833–844.

Devereux, M. B. & Engel, C. (2003), 'Monetary Policy in the Open Economy Revisited: Price Setting and Exchange-Rate Flexibility', *The Review of Economic Studies* **70**(4), 765–783.

ECB (2011), *The Monetary Policy of the ECB*, 3 edn, European Central Bank, Frankfurt am Main.

ECB (2016), Exchange rate pass-through into euro area inflation, Economic Bulletin Issue 7, European Central Bank.

Forbes, K., Hjortsoe, I. & Nenova, T. (2018), 'The shocks matter: Improving our estimates of exchange rate pass-through', *Journal of International Economics* **114**(C), 255–275.

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

Goldberg, P. K. & Knetter, M. M. (1997), 'Goods Prices and Exchange Rates: What Have We Learned?', *Journal of Economic Literature* **35**(3), 1243–1272.

Ha, J., Stocker, M. & Yilmazkuday, H. (2019), Inflation and Exchange Rate Pass-Through, Policy Research Working Paper 8780, World Bank.

Hahn, E. (2003), Pass-through of external shocks to euro area inflation, Working Paper Series 243, European Central Bank.

Jašová, M., Moessner, R. & Takáts, E. (2016), Exchange rate pass-through: What has changed since the crisis?, BIS Working Papers 583, Bank for International Settlements.

Jordà, O. (2005), 'Estimation and Inference of Impulse Responses by Local Projections', *American Economic Review* **95**(1), 161–182.

Kiliç, R. (2016), 'Regime-Dependent Exchange-Rate Pass-Through to Import Prices', *International Review of Economics & Finance* **41**(C), 295–308.

Osbat, C., Sun, Y. & Wagner, M. (2019), Sectoral Exchange Rate Pass-Through in the Euro Area, Working paper series forthcoming, European Central Bank.

Özyurt, S. (2016), Has the Exchange Rate Pass-Through Recently Declined in the Euro Area?, Working Paper Series 1955, European Central Bank.

Pollard, P. S. & Coughlin, C. C. (2004), Size matters: asymmetric exchange rate pass-through at the industry level, Working Papers 2003-029, Federal Reserve Bank of St. Louis.

Przystupa, J. & Wróbel, E. (2011), 'Asymmetry of the Exchange Rate Pass-through', *Eastern European Economics* **49**(1), 30–51.

Razafindrabe, T. (2017), 'Nonlinearity and Asymmetry in the Exchange Rate Pass-Through: What Role for Nominal Price Stickiness?', *Review of International Economics* **25**(4), 711–732.

Teulings, C. N. & Zubanov, N. (2014), 'Is Economic Recovery a Myth? Robust Estimation of Impulse Responses', *Journal of Applied Econometrics* **29**(3), 497–514.

Webber, A. G. (2000), 'Newton's Gravity Law and Import Prices in the Asia Pacific', *Japan and the World Economy* **12**(1), 71 – 87.

A Annex

Table A1: Descriptive Statistics

	Extra-euro area nominal effective exchange rate (import weights)			Consumer Prices		Import Prices	
	log change (%)	% of total		log change (%)		log change (%)	
	St.deviation (large change threshold)	Depreciations	Large changes	Mean	St.deviation	Mean	St.deviation
EA	2.3%	46%	29%	0.4%	0.3%	0.2%	1.3%
DE	2.9%	47%	31%	0.4%	0.3%	0.1%	1.3%
FR	3.3%	46%	32%	0.4%	0.3%	0.1%	1.3%
IT	3.2%	46%	28%	0.4%	0.3%	0.4%	1.7%
ES	3.3%	46%	32%	0.5%	0.5%	0.4%	1.7%
NL	3.2%	47%	31%	0.5%	0.4%	0.2%	1.7%
BE	3.4%	46%	32%	0.5%	0.4%	0.3%	1.5%
AT	3.3%	46%	30%	0.4%	0.3%	0.3%	1.0%
PT	3.6%	47%	34%	0.5%	0.5%	0.2%	1.8%
FI	2.8%	44%	30%	0.4%	0.4%	0.2%	1.7%
GR	3.3%	45%	37%	0.5%	0.6%	0.4%	2.1%
IE	2.9%	47%	30%	0.4%	0.6%	0.3%	2.0%
LU	3.8%	46%	36%	0.5%	0.6%	0.7%	1.9%
	Countries that joined the euro area after 2007						
SK	3.0%	43%	31%	0.9%	1.2%	0.4%	2.0%
LT	3.3%	32%	23%	0.6%	0.9%	0.2%	4.0%
SI	3.3%	46%	31%	0.6%	0.7%	0.6%	1.5%
LV	2.9%	46%	17%	0.9%	1.1%	0.8%	2.6%
EE	3.3%	45%	29%	0.8%	0.8%	0.4%	1.6%
CY	3.2%	47%	33%	0.4%	0.7%	0.3%	0.7%
MT	2.8%	45%	32%	0.5%	0.5%	0.5%	3.8%

Note: Consumer prices refer to Headline Harmonised Index of Consumer Prices; import prices refer to Import deflator of goods and services; descriptive statistics calculated over 1997Q1 to 2019Q1.

B Annex

Table B1: Linear ERPT with Unemployment Gap

	Import prices			Consumer prices		
	Impact	1 year	2 years	Impact	1 year	2 years
EA	0.21*	0.42*	0.27*	0.02	0.04	0.04
DE	0.29*	0.58*	0.49*	0.04*	0.06*	0.09*
FR	0.20*	0.36*	0.31*	0.04*	0.03	0.06*
IT	0.43*	0.69*	0.56*	0.03*	0.06*	0.09*
ES	0.24*	0.57*	0.48*	0.06*	0.10*	0.12*
NL	0.23*	0.36*	0.29*	0.01	0.06*	0.16*
BE	0.29*	0.49*	0.47*	0.07*	0.11*	0.14*
AT	0.36*	0.56*	0.48*	0.05*	0.12*	0.15*
PT	0.32*	0.56*	0.44*	0.03	0.07*	0.13*
FI	0.24*	0.36*	0.13	0.04*	0.08*	0.13*
GR	0.22*	0.16	0.32*	0.05*	0.05	0.04
IE	0.43*	0.32*	0.12	0.04	0.11	0.18
LU	0.36*	0.57*	0.29	0.12*	0.15*	0.16*
Countries joining the euro area after 2007						
SK	0.06	0.18*	0.18	-0.03	-0.10	-0.31*
LT	0.30	0.51*	0.76*†	0.02	0.17	0.24
SI	0.41*	0.84*†	0.57*	0.05*	-0.05	-0.03
LV	0.22*	0.26	0.22	0.02	0.08	0.01
EE	0.11*	0.23*	0.16*	0.09*	0.17	0.17
CY	0.07*	0.16*	0.10*	0.01	0.02	0.03
MT	0.05	0.49*	0.35*	0.04*	0.08*	0.01

Note: The asterisk $*$ indicates that the coefficient is significantly different from zero; the dagger † indicates that it is not significantly different from unity. The level of significance is 5% in all cases.

Table B2: ERPT with Unemployment Gap: Sign Non-linearity

	Import Prices						Consumer Prices					
	Euro Depreciation			Euro Appreciation			Euro Depreciation			Euro Appreciation		
	Impact	1 Year	2 Years	Impact	1 Year	2 Years	Impact	1 Year	2 Years	Impact	1 Year	2 Years
EA	0.11	0.07	**-0.13**	0.29*	0.68*†	**0.57***	0.03	0.00	**-0.08**	0.01	0.08	**0.13***
DE	**0.21***	0.30	0.68*†	**0.38***	0.86*†	0.30	0.04	0.00	0.06	0.03	0.11*	0.12*
FR	0.14*	**0.09**	0.44	0.27*	**0.65***	0.16	0.05*	0.02	0.11*	0.03	0.05	0.00
IT	0.42*	0.47	0.89*†	0.44*	0.92*†	0.21	0.03	0.04	0.16*	0.04*	0.08*	0.01
ES	0.15	0.30	0.61*†	0.34*	0.85*†	0.34	0.04	**-0.02**	0.13	0.07*	**0.22***	0.12
NL	0.14	0.10	0.43	0.32*	0.63*	0.14	0.03	0.05	0.15*	-0.01	0.07	0.17*
BE	0.23*	0.21	0.67*†	0.35*	0.74*†	0.26	0.08*	0.06	0.13	0.06*	0.15*	0.15*
AT	0.31*	0.55*	**0.91***†	0.40*	0.57*	**0.01**	0.03	**0.06**	0.18*	0.07*	**0.17***	0.11
PT	0.25*	**0.14**	0.41	0.39*	**1.04***†	0.50	0.03	**-0.06**	0.05	0.04	**0.22***	0.23*
FI	0.19*	0.12	0.39	0.28*	0.56*	-0.08	0.06*	0.07	0.03	0.02	0.09*	0.21*
GR	0.18	**-0.21**	0.16	0.25	**0.50***	0.45	**0.10***	0.08	0.20	**0.00**	0.03	-0.12
IE	0.51*	0.39	0.20	0.34*	0.23	0.02	0.03	0.04	0.08	0.05	0.19*	0.32*
LU	0.31*	0.48*	0.45*	0.40*	0.67*†	0.08	0.14*	0.16*	**0.30***	0.11*	0.13*	**0.01**
Countries joining the euro area after 2007												
SK	0.09	0.29	0.21	0.03	0.10	0.16	0.07	0.16	**0.04**	-0.09	-0.28*	**-0.54***
LT	0.40	0.09	0.91	0.24	0.80*†	0.64	0.09	0.15	-0.05	-0.03	0.18	0.46*
SI	0.47*	1.03*†	**1.20***†	0.32*	0.56*	**-0.35**	0.05	-0.16	-0.12	0.05	0.07	0.09
LV	0.20	0.02	-0.16	0.24	0.54	0.72	0.04	-0.23	-0.74	0.00	0.46*	1.02*
EE	0.12	0.07	0.22	0.11	0.34*	0.12	**0.20***	0.21	0.04	**0.01**	0.14	0.28
CY	0.06*	0.06	0.17	0.09*	0.25*	0.01	0.02	-0.01	0.09	0.01	0.06	-0.05
MT	-0.17	0.46*	0.42*	0.27	0.51*	0.28*	0.10*	**0.17***	0.07	-0.01	**-0.02**	-0.06

Note: The asterisk ∗ indicates that the coefficient is significantly different from zero; the dagger † indicates that it is not significantly different from unity; bold indicates statistically significant differences between depreciations and appreciations. The level of significance is 5% in all cases.

Table B3: ERPT with Unemployment Gap: Size Non-linearity

	Import Prices						Consumer Prices					
	Large Change			Small Change			Large Change			Small Change		
	Impact	1 Year	2 Years	Impact	1 Year	2 Years	Impact	1 Year	2 Years	Impact	1 Year	2 Years
EA	0.24*	**0.60***	0.32*	0.12	**-0.12**	0.12	0.03*	**0.08***	0.08*	0.00	**-0.07**	-0.02
DE	0.30*	0.66*	0.58*	0.28*	0.37*	0.20	0.03*	0.06*	0.10*	0.05*	0.05	0.05
FR	**0.17***	0.42*	**0.48***	**0.28***	0.18	**-0.16**	0.03*	0.04	0.08*	0.06*	0.02	0.01
IT	0.42*	**0.86****†	**0.72**†	0.45*	**0.38***	**0.23**	0.02*	0.07*	0.09*	0.05*	0.05	0.08
ES	0.20*	0.65*	**0.67***	0.36*	0.34*	**-0.09**	**0.04***	0.10*	0.10*	**0.10***	0.09	0.18*
NL	0.21*	**0.47***	**0.57***	0.28*	**0.08**	**-0.49***	**-0.01**	**0.02**	0.12*	**0.07***	**0.17***	0.27*
BE	0.29*	**0.64***	0.60*	0.29*	**0.15**	0.20	0.07*	0.12*	**0.19***	0.08*	0.08	**0.04**
AT	0.34*	0.59*	0.51*	0.41*	0.50*	0.43*	0.04*	0.13*	0.17*	0.06*	0.09	0.11
PT	0.28*	0.65*	0.52*	0.41*	0.32	0.21	0.03	0.08*	0.12*	0.03	0.06	0.14*
FI	0.27*	0.41*	0.04	0.13	0.24	0.38	**0.06***	0.10*	0.16*	**-0.01**	0.01	0.04
GR	0.19*	0.15	0.27*	0.33*	0.19	0.51†	0.05*	0.06	0.04	0.04	0.02	0.01
IE	0.44*	**0.44***	**0.24***	0.39*	**0.06**	**-0.18**	0.04	0.14	**0.28***	0.03	0.05	**-0.01**
LU	0.31*	0.61*	0.32	0.45*	0.50*	0.24	0.12*	0.17*	0.17*	0.14*	0.11*	0.16*
Countries joining the euro area after 2007												
SK	0.04	0.18*	0.18*	0.11	0.14	0.18	-0.05	-0.16*	**-0.41***	0.07	0.12	**0.07**
LT	0.32	0.53	**0.55**	0.24	0.41	**1.64**	0.04	0.19	0.26	-0.04	0.05	0.15
SI	0.40*	0.87*†	0.63*	0.45*	0.76*†	0.42	0.04	-0.07	-0.09	0.08*	0.00	0.12
LV	0.17	0.15	0.25	0.40*	0.62*†	0.15	0.02	0.06	-0.01	0.05	0.17	0.08
EE	0.13*	0.28*	0.19*	0.03	0.06	0.07	**0.12***	0.23*	0.19	**0.01**	-0.06	0.14
CY	0.07*	0.17*	0.06	0.09*	0.11	0.21*	0.00	0.02	0.04	0.06	0.04	-0.01
MT	-0.04	0.50*	0.39*	0.25	0.47*	0.32*	**0.01**	0.05	0.00	**0.12***	0.16*	0.03

Note: The asterisk ∗ indicates that the coefficient is significantly different from zero; the dagger † indicates that it is not significantly different from unity; bold indicates statistically significant differences between large and small exchange rate changes. The level of significance is 5% in all cases.

C Annex

Table C1: ERPT to Extra-euro area Import Prices with Output Gap

	Linear			Sign Non-Linearity						Size Non-Linearity					
				euro depreciation			euro appreciation			large change			small change		
	Impact	1 year	2 years	Impact	1 year	2 years	Impact	1 year	2 years	Impact	1 year	2 years	Impact	1 year	2 years
EA	0.41*	0.68*†	0.24	0.28*	0.46	0.10	0.51*	0.85*†	0.35	0.45*	**0.85***†	0.21	0.30*	**0.14**	0.33
DE	0.36*	0.64*	0.58*	**0.22***	**0.23**	0.58*†	**0.50***	**1.03***†	0.53	0.37*	0.71*	0.61*	0.35*	0.44*	0.39
FR	0.25*	0.39*	0.32*	0.20*	**0.02**	0.42	0.29*	**0.80***†	0.20	0.22*	0.46*	**0.48**	0.34*	0.20	**-0.12**
IT	0.70*	0.99*†	0.76*†	0.69*	0.67	1.12*†	0.71*	1.31*†	0.35	0.68*	1.15*†	1.00*†	0.73*	0.70*†	0.32
ES	0.50*	0.94*†	0.83*†	0.38*	0.44	1.08*†	0.63**	1.47*†	0.55	0.45*	**1.13***†	**1.21***†	0.65*	**0.47**	**-0.26**
NL	0.26*	0.39*	0.35*	0.08	0.19	0.69*†	0.44*	0.57*	-0.02	0.24*	**0.51***	**0.70***	0.32*	**0.08**	**-0.55***
BE	0.44*	0.54*	0.43*	0.37*	0.65*†	**0.82***†	0.52*	0.39	**-0.09**	0.42*	0.60*	0.53*	0.50*	0.38	0.21
AT	0.59*	0.99*†	0.69*†	0.60*	1.06*†	0.99*†	0.58*	0.93*†	0.33	0.59*	1.02*†	0.72*†	0.59*	0.91*†	0.46*
PT	0.86*†	0.94*†	0.64*†	**0.65***	0.26	0.85	**1.10***†	1.80*†	0.54	0.79*	1.12*†	0.84*†	1.03*†	0.49	0.13
FI	0.20*	0.31*	0.28*	0.22*	0.07	0.39	0.18	0.52*	0.18	0.21*	0.31*	0.20	0.14	0.29	0.55*†
Countries joining the euro area after 2007															
SK	0.04	0.33*	0.33*	-0.03	0.33*	0.43	0.10	0.33*	0.25	0.02	0.31*	0.31*	0.13	0.40*	0.44
LV	0.30	0.44*	0.17	0.41	0.16	-0.25	0.24	0.60*†	0.42	0.24	0.30	0.02	0.51	0.87	0.65
EE	0.01	0.25*	0.22*	-0.14	0.14	0.37*	0.13	0.34*	0.07	-0.02	0.30*	0.26*	0.11	0.13	0.10

Note: The asterisk $*$ indicates that the coefficient is significantly different from zero; the dagger † indicates that it is not significantly different from unity; bold indicates statistically significant differences between depreciations versus appreciations (sign non-linearity) and large versus small exchange rate changes (size non-linearity). The level of significance is 5% in all cases.

D Annex

Figure D1: Import prices

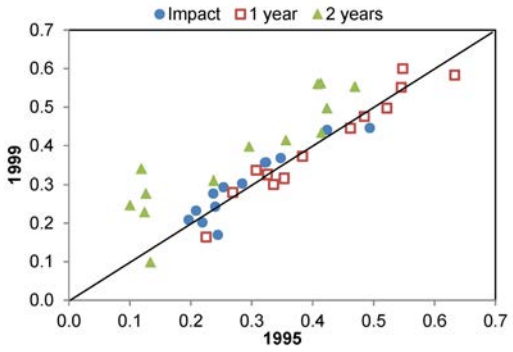


Figure D2: Consumer prices

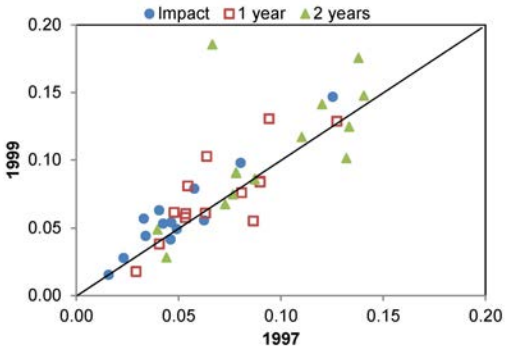


Table D1: Robustness of Non-linearities Across Samples

	Import Prices						Consumer Prices			
	Sign Non-linearity			Size Non-linearity			Sign Non-linearity		Size Non-linearity	
	95-2019Q1	97-2019Q1	99-2019Q1	95-2019Q1	97-2019Q1	99-2019Q1	97-2019Q1	99-2019Q1	97-2019Q1	99-2019Q1
EA	0	0	0	L	L	L	0	0	L	L
DE	A	A	A	L	0	L	A	A	0	S
FR	A	A	A	L	L	0	0	0	0	0
IT	0	0	0	0	0	L	0	0	0	0
ES	A	A	A	0	L	L	A	A	S	S
NL	0	0	0	L	L	L	0	0	S	S
BE	0	D	D	0	S	0	D	0	0	S
AT	0	0	0	0	0	S	0	0	0	0
PT	A	A	A	0	L	L	A	0	0	0
FI	0	0	0	L	L	0	0	D	L	0
GR	A	0	0	0	0	0	D	D	0	0
IE	D	D	D	L	0	0	0	0	L	0
LU	0	D	D	S	S	S	D	D	0	0

Note: Labels D (A) denotes statistically significant sign non-linearity with higher impact after depreciations (appreciations); Labels L (S) denote statistically significant size non-linearity with higher impact after large (small) changes in the exchange rate.

Acknowledgements

Our work has greatly benefited from the suggestions and feedback of Chiara Osbat and Paolo Guarda. We would like to thank Marek Jarociński, Michele Lenza, Carlos Montes-Galdón, Georg Strasser, Srečko Zimic, and Vanessa Gunnella and the participants in the meetings organised by the ESCB Expert group on Exchange Rate Pass-through for useful comments and discussions. All replication files can in principle be obtained from the authors upon request. However, a subset of the time series used in our analysis is confidential. The views expressed in this paper are those of the authors and do not necessarily represent the official views of Banque centrale du Luxembourg, the European Central Bank, or the Eurosystem.

Roberta Colavecchio
Banque centrale du Luxembourg, Luxembourg, Luxembourg; email: roberta.colavecchio@bcl.lu

Ieva Rubene
European Central Bank, Frankfurt am Main, Germany; email: ieva.rubene@ecb.europa.eu

Postal address 60640 Frankfurt am Main, Germany
Telephone +49 69 1344 0
Website www.ecb.europa.eu

PDF ISBN 978-92-899-4005-4 ISSN 1725-2806 doi:10.2866/997922 QB-AR-20-014-EN-N