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Research Article

Estimates of the exchange rate pass-through to consumer prices in Malta

G. Abela[1,2]**, N. Rapa**[*2]
[1] *Department of Economics, Faculty of Economics, Management and Accountancy, University of Malta, Msida, Malta*
[2] *Central Bank of Malta, Pjazza Kastilja, Valletta, Malta*

Abstract. The Exchange Rate Pass-Through (ERPT), commonly defined as the extent to which exchange rate changes are reflected in the price levels of an economy, has important implications in a number of policy-relevant areas. Despite this, estimates of ERPT in the Maltese economy are scarce and do not take into account changes in the monetary regime pertaining to the adoption of the euro. We use local projections to estimate linear and non-linear ERPT to consumer prices in Malta after adoption of the euro. In line with literature, results point at incomplete ERPT to headline consumer prices, peaking at around 20% by the end of the first year after the exchange rate shock. ERPT to overall Harmonised Index of Consumer Price (HICP) inflation is largely driven by the goods component while ERPT to services prices is largely insignificant across the horizon considered. Allowing for non-linearities, we find evidence of asymmetric pass-through with larger changes to, as well as depreciations in, the nominal effective exchange rate being consistent with larger pass-through estimates.

1 Introduction

Exchange Rate Pass-Through (ERPT) is commonly defined as the extent to which exchange rate changes are reflected in the price levels of an economy, most commonly import and consumer prices. The relationship between changes in exchange rates and local prices has very important implications both from theoretical and policy perspectives. Theoretically, incomplete ERPT estimates might indicate deviations in relative purchasing power parity (PPP) which predicts that changes in prices of goods should be the same across locations when all prices are converted to a common currency (Burstein & Gopinath, 2014). This in turn has important implications on the extent of firm market power, on the market structures operating in an economy as well as on the efficiency in the allocation of goods across countries.

The study of ERPT to local prices also has important implications for monetary policy, especially in an open economy setup. On the one hand, exogenous shocks to the nominal effective exchange rate are a source of inflation fluctuations which need to be stabilised through monetary policy. On the other hand, changes in monetary policy in response to inflationary shocks which are exogenous to exchange rate shocks, have an indirect effect on the nominal effective exchange rate which could help stabilise inflation further. Thus, the extent of ERPT to local prices, especially in open economy setups can be both a source and a stabilising force for inflation which needs to be internalised in the monetary policy decisions of monetary authorities.

The transmission of exchange rate movements to consumer prices can be categorised into three distinct channels. First, exchange rate shocks can be directly transmitted to the overall consumer price level through changes in the prices of imported final consumer goods. Secondly, a movement in the exchange rate is expected to affect the prices of imported intermediate production used for domestically produced commodities which then indirectly affect consumer prices. Finally, developments in the exchange rate also affect the price competitiveness of domestic products on international markets, thus leading to changes in domestic output levels, factor demands and consequently factor prices which are ultimately transmitted to the prices of final domestic production which is consumed locally.

We use local projections (LP) to produce ERPT estimates for consumer prices in Malta after its accession to the European Monetary Union. A key advantage of LPs, which will be further explained in section 3, is their

**Correspondence to*: N. Rapa (rapan@centralbankmalta.org)

flexibility in allowing for non-linearities.[1] Indeed, in our specifications, we also allow for non-linear pass-through estimates both in terms of the size and direction of the change in Malta's nominal effective exchange rate. In line with literature, results point at incomplete ERPT estimates for consumer prices, peaking at around 20% by the end of the first year after the shock. Secondly, ERPT to overall HICP inflation seems to be largely driven by the goods component (in particular by the food and energy sub-indices) while ERPT to services are largely insignificant across the horizon considered. Thirdly, we find evidence of asymmetric pass-through with larger changes to as well as depreciations in the nominal effective exchange rate being consistent with larger pass-through estimates.

Our work makes multiple contributions to the study of ERPT in the Maltese economy. The two available estimates in the literature are based on data samples which encompass different monetary regimes. We therefore expect to obtain more reliable estimates by using data from 2008 onwards. Second, in contrast to available literature, we estimate ERPT to prices at increasingly disaggregated levels, in order to build a more comprehensive picture of what forces drive the headline estimates.

The rest of the paper is structured as follows. Section 2 provides a discussion on the main factors impacting ERPT estimates and existent estimates for euro area economies. Section 3 describes the methodology utilised in this study. Finally, section 4 provides results for linear and non-linear ERPT estimates for headline HICP and subcomponents together with a battery of robustness tests, while section 5 summarises and concludes.

2 Literature Review

2.1 Factors impacting ERPT

Literature identifies several structural factors that can impact the extent of ERPT to prices in a particular economy. All other factors kept constant, the greater the extent of openness to imports of an economy, the greater is the potential exposure of its prices to exchange rate impacts (Ortega & Osbat, 2020). For euro area countries, this is particularly the case with openness to extra-euro-area trade (Campa & Gonzalez Minguez, 2006). However, the larger degree of ERPT in open economies is usually attenuated by other factors such as currency of invoicing chosen by foreign exporters, integration in Global Value Chains (GVCs) as well as market power and competitive structure of firms. Both theoretical and empirical evidence suggest that when a large share of the inputs used in the production of exports is sourced from the destination market, the pass-through of exchange rate fluctuations to import (and consequently export) prices will be low. Indeed, a change in the bilateral exchange rate of the export market currency has two counteracting effects, in essence acting as a hedging mechanism for both foreign and local exporter from deviations in their profit mark-ups, ultimately contributing to lower ERPT estimates (Ortega & Osbat, 2020).

The degree of competition and market structures, both in the import and export markets, also impact the extent of ERPT. Smaller importers with weaker bargaining power are less able to limit ERPT to import prices, all else equal, but the extent of pass-through also depends on the conditions faced by exporters (Özyurt, 2016).

Closely tied to this is the currency of invoicing of imports. The literature typically distinguishes between producer currency pricing (PCP), where imports are priced in the currency of the producer, and local currency pricing (LCP), where imports are priced in the currency of the destination market. With PCP, prices are adjusted in the producer's currency, which theoretically leads to full pass-through since the products automatically become relatively more or less expensive in the currency of the buyer as the exchange rate adjusts. On the other hand, prices quoted in the currency of the buyer will not adjust by default given changes to the exchange rate, with the impact being absorbed by the exporter's mark-up (Ortega & Osbat, 2020).

Since exchange rate pass-through tends to vary by sector (Campa & Goldberg, 2002), the aggregate ERPT for an economy is also affected by the composition of its imports. In turn, sectoral pass-through tends to vary with the degree of homogeneity of the products in question, with ERPT being higher for more homogenous products and lower for highly differentiated products (Ben Cheikh & Rault, 2017).

An aspect which has gained increasing attention in the ERPT literature is the presence of non-linearities. In particular, the size and dynamics of ERPT differ according both to the sign of exchange rate changes (sign non-linearity) and to the magnitude of exchange rate changes (size non-linearity). The former type of non-linearity is a consequence of factors leading to downward price rigidities, mainly driven by the competitive structures that exporting firms are operating in, which drive their pricing-to-market decisions. For instance, in imperfectly competitive structures, the higher an exporting firm's market power in the destination market, the lower the incentive to pass-through exchange rate appreciations, meaning that depreciations result in higher ERPT than appreciations (Brun-Aguerre et al., 2016; Delatte & López-

[1] Additionally, LP methods are usually more robust to misspecifications of the Data Generating Process (DGP) when compared to AR or VAR setups as they directly estimate impulse responses at all horizons.

Villavicencio, 2012).

Literature rationalises size non-linearities through the existence of menu costs and the presence of switching costs in import markets (Ben Cheikh, 2012; Bussière, 2007). In the presence of costs associated with price adjustments, exporters may choose to adjust prices only after relatively large exchange rate changes. Conversely, if domestic consumers face costs in switching to rival products, exporters can allow their prices to vary in the importer's currency as long as the variation does not exceed the switching costs, implying greater pass- through for smaller exchange rate changes.

Another growing branch of the ERPT literature is that relating to shock dependence in ERPT. Shock dependence is the proposition that the degree of ERPT depends on the nature of the underlying or structural shock causing the exchange rate movement in the first place. Shock dependence can therefore provide an explanation to why the degree of pass-through can vary over time for a particular economy. An early contribution to this literature is the work carried out by Shambaugh (2008), who employs a VAR model with long-run restrictions to relate the changes between consumer and import prices and exchange rates to several structural shocks.

More recently, structural VARs have been applied by Comunale and Kunovac (2017) and Forbes et al. (2018) whilst Local Projections have been used by Comunale (2019), to provide evidence on shock dependence in ERPT to prices in the euro area, the UK and Baltic states respectively. A more structural approach to shock dependent ERPT estimates has been used by Burlon et al. (2018) who estimate shock-dependent ERPT through a DSGE model.

2.2 ERPT estimates in the literature

In general, ERPT is found to be 'incomplete', in the sense that both import and retail prices tend to change less-than-proportionately following exchange rate adjustment. Menon (1995) provides a survey of ERPT pass-through studies conducted over a broad sample period spanning from 1974 to 1994. Most studies surveyed yield incomplete pass-through estimates for exchange rate deviations on both import and consumer prices both in the long and short run. Moreover, the survey has identified significant inter- and intra-country differences in ERPT estimates highlighting the importance of country-specific factors in shaping the extent of ERPT in both short and long run.

More recent literature focusing on the euro area shows that ERPT to import and consumer prices for the euro area and its member states are incomplete both in the short and long run. On impact ERPT to import prices for the euro area as a whole vary from 0.20, as reported in Colavecchio and Rubene (2020), to 0.64 in Ben Cheikh and Rault (2017). ERPT to import prices is found to generally increase to between 0.33 in Colavecchio and Rubene (2020) and 0.80 in Comunale and Kunovac (2017) in the first year after the shock. The former study also finds that the response of import prices to exchange rate fluctuations peaks after 1 year, giving rise to a 'hump-shaped' pattern that is found for almost all individual euro area states. ERPT estimates to consumer prices are found to increase monotonically after the exchange rate shock and are generally found to be lower than those for import prices in all euro area states. For the euro area as a whole, ERPT to consumer prices after 1 year is of 0.04 (and not significantly different from zero) in Colavecchio and Rubene (2020) and ranges between 0.01 and 0.04 in Ortega and Osbat (2020). Using structural models, Comunale and Kunovac (2017) estimate a coefficient of less than 0.2 a year, whilst Burlon et al. (2018) estimate ERPT to retail prices at around 0.04 per quarter (for non-oil imports from the rest of the world). Colavecchio and Rubene (2020) and Ortega and Osbat (2020) further show that these euro area-wide estimates hide considerable cross-country heterogeneity which is in turn driven by the different structural characteristics of euro area countries.

There have been fewer studies specifically focusing on the issue of non-linear ERPT. Most studies find evidence of both size and sign non-linear ERPT to both consumer and import prices. However, evidence is quite mixed and shows a substantial level of heterogeneity across countries and studies. For instance, Ben Cheikh (2012) finds strong evidence of size non linearities across all euro area states, with larger exchange rate adjustments being consistent with larger ERPT to consumer prices. The same study however finds less clear-cut evidence for sign non-linearities. On the other hand, Colavecchio and Rubene (2020) have no clear-cut results, with the effects of both size and sign non-linearities being extremely heterogeneous across countries and not present in all euro area members. Meanwhile, Delatte and López-Villavicencio (2012) examine sign asymmetry in pass-through to consumer prices for four major countries, the US, the UK, Germany and Japan, finding strong evidence that depreciations are passed through more strongly than appreciations in both the short run and long run in all countries in the sample. Brun-Aguerre et al. (2016) find, for a panel of 19 developed and 14 emerging market countries, that depreciations are generally passed through more than appreciations, with no significant differences between the two groups.

2.3 The case for Malta

The Maltese economy is highly trade-open and characterised by firms which are small by international standards, despite the presence of some multinational firms. As of 2019, Malta's total imports of goods and services as a share of GDP stood at 118.6%, one of the highest values in the euro area. More importantly, as seen in Figure 1, Malta's share of extra-euro area imports as a proportion of GDP is the second-highest in the euro area. All else equal, these factors point at considerably large exposures of local import and consumer prices to exchange rate fluctuations. Nonetheless, a deeper look at Maltese trade data uncovers that approximately half of all extra-euro-area imports of goods in the Maltese economy are invoiced in euro, again one of the highest in the euro area, as shown in Figure 2. In theory this should act as a counterbalancing factor to the high degree of openness of the economy, thus reducing the expected pass-through to domestic prices.

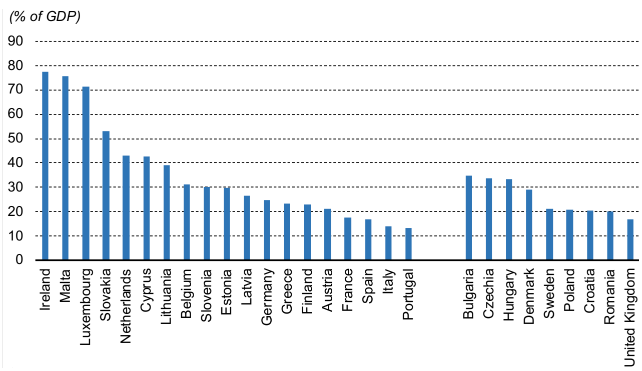

Figure 1: Share of extra EA total Imports in GDP. *Source: Authors' Calculations.*

A similar conclusion may be reached when looking at ERPT from a sectoral perspective. Namely, listing imports by SITC category, one can note that the vast majority of goods imports for Malta are made up of categories 3 (Mineral fuels, lubricants, and related materials) and 7 (machinery and transport equipment). Looking at sectoral ERPT findings estimated by Ben Cheikh and Rault (2017), one can note that while ERPT estimates for goods falling under SITC category 3 are usually very close to 1 (i.e. perfect pass-through), ERPT for sector 7 goods is often found to be statistically not different from zero. Thus, similar to the previous discussion, it is very likely that even when looking at the sectoral composition of goods imports for Malta, there are compensating forces that on the one hand contribute positively to a high degree of exchange pass-through, while on the other serve to attenuate the effects of exchange rate fluctuations to aggregate domestic prices.

In their cross-country comparisons, Colavecchio and Rubene (2020) and Ortega and Osbat (2020) find that Malta's estimates for ERPT to consumer prices are quite in line with euro area economies peaking at around 0.1. Interestingly, the former study finds that Malta's ERPT to consumer prices is lower than other very small and open economies such as Luxembourg. Moreover, contrary to virtually all other euro area states, Malta's ERPT to consumer prices peaks in the first year after the shock, with the second year showing point estimates very close to zero which are also statistically insignificant.

However, it is important to note that both these papers make use of data spanning from 1999 to 2017, a period during which Malta was under two different monetary regimes. The adoption of the euro and consequently of a floating exchange rate regime led to a clear break in the variability of the exchange rate series. We believe that results gleaned from datasets which encompass the different monetary regimes could be affected by this feature of the data and must therefore be treated with a degree of caution. In this light, we attempt to control for this change in monetary regime by starting our estimation period from 2008, the year of Malta's accession to the European Monetary Union. Moreover, in our study we estimate ERPT estimates for HICP subcomponents in an effort to uncover the main drivers behind overall results.

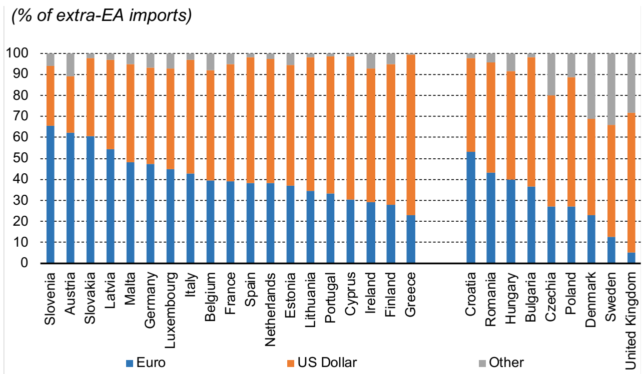

Figure 2: Shares of invoicing currencies of imports from outside the EA. *Source: Authors' Calculations.*

3 Methodology

3.1 Overview of the model

We make use of an LP specification largely based on the model of Colavecchio and Rubene (2020). LP methods, originally proposed by Jordà (2005), yield estimates of impulse response functions of the variable of interest over chosen forecast horizons. This is achieved by regressing the dependent variable at time $t + h$ given the information set at time t for each value of h, where $t = 1, 2, ..., T$ denotes the time dimension of the data and $h = 0, 1, 2, ..., H < T$ denotes each forecast horizon. As illustrated below, the response of the dependent variable at a given forecast horizon to a shock in the variable of interest is given by the path of the estimated coefficient of the explanatory variable in question in each successive regression, pertaining to each value of h.

LP models possess certain advantages over more other techniques used to estimate IRFs, such as VAR models. The method is more robust to misspecification of the DGP, estimating a new set of coefficients at each forecast horizon. More precisely, LP models directly estimate the pointwise estimates of IRFs, contrary to VARs, which do so through an iterative process that compounds any errors in the parameter estimates as the horizon h increases (Jordà, 2005). Moreover, LP models are considerably more accommodative of non-linear specifications, making them very useful and therefore popular in applied macroeconomic work.

These characteristics make LP estimation particularly suitable for our purposes, although one must also be wary of its weaknesses. The main drawback of LP models is their data consuming nature. While VARs consume degrees of freedom across the lag and number of variable dimensions, LP models actually reduce the sample size as h increases (Caselli & Roitman, 2019). Therefore, LP estimates tend to become more uncertain over longer time horizons h. This loss of efficiency can be addressed by expanding the information set through including in each regression the error term from the previous horizon estimation (Carriere-Swallow et al., 2016; Teulings & Zubanov, 2014). Our model takes the following form:

$$p_{t+h}-p_{t-1} = \alpha(h)+\phi(h)\Delta e_t+\sum_{i=0}^{k}\mathbf{x}'_{t-i}(h)\gamma_i(h)+u_{t+h}(h)$$

where p_t and e_t are the natural logs of the HICP and the nominal effective exchange rate (NEER) indices respectively, $\mathbf{x}_t$ is a vector of control variables and u_{t+h} is the error term in each regression pertaining to each forecast horizon h. The dependent variable therefore measures the cumulative change in the price level between $t-1$ and the forecast period $t+h$. The impulse response of cumulative price inflation at each forecast horizon given an exchange rate change at time t is then given by:

$$\begin{aligned} IR_{h,t} =& E(p_{t+h} - p_{t-1}|\Delta e_t \neq 0) - E(p_{t+h} - p_{t-1}|\Delta e_t = 0) \\ =& \phi(h) \end{aligned}$$

Therefore, an impulse response function (IRF) of price inflation responses over all forecast horizons given an exchange rate change at time t is obtained by running a collection of H regressions and plotting the path of $\phi(h)$ over all horizons.

Our control variables are the output gap, as a measure of economic slack, and the index of foreign prices evaluated in foreign currencies (in log differences) to account for domestic and imported sources of price pressures, lagged values of inflation and log-differenced exchange rates to control for serial dependence, as well as the previous-horizon error terms. The appropriate lag length k for each of our control variables at each forecast horizon is selected by means of an algorithm that minimises the Akaike Information Criterion (AIC) for each estimated regression. This process excludes the lagged error terms, where only the previous horizon residuals are included in each equation.[2]

To provide a comprehensive analysis of the characteristics and dynamics of ERPT to consumer prices in Malta, we first use headline HICP as our dependent variable, and subsequently dig deeper by re-estimating the model for different HICP sub-indices. In the final part of this study, we allow for the possibility of non-linear responses of ERPT to headline consumer price inflation, as detailed in the following sections.

In all these instances, for the purpose of interpreting our results, it should be noted that since our NEER index is defined in terms of foreign currency per euro, an increase in the NEER signifies an appreciation of the euro, such that a priori our ERPT coefficients are expected to be negative. We estimate our model using data from 2008 Q1 to 2019 Q4. We choose 2008 Q1 as the start of our sample period in order to account for Malta's adoption of the euro on 1 January 2008. The adoption of the euro signified a change in Malta's monetary regime from a fixed to a floating exchange rate and as expected, materially affected the volatility of the NEER, with a clear break in volatility before and after the start of our sample. Encompassing such volatility within a longer sample would necessarily impact the reliability of our results; hence, we provide estimates using solely data pertaining to 2008 and later. On the other hand, we choose to stop our estimation in 2019 Q4 so that we do not include the COVID-19 period in our estimation sample, as this could potentially create biases in the results obtained.

3.2 Data

Our reference exchange rate variable is the Nominal Effective Exchange Rate (NEER) on the import side as sourced from the Eurosystem Macroeconomic Projection Database. This NEER index is an arithmetic single-

[2] Additionally, we perform a battery of sensitivity tests by augmenting our model with additional control variables including Brent crude oil prices, migrants' share of the labour force and the unemployment gap.

weighted effective exchange rate with weights reflecting the importance each of the 36 countries has in the Maltese import basket. We rebase this measure in terms of foreign currency per euro such that an increase in the index shows an appreciation of the NEER. The foreign prices variable is an index of extra euro area competitor's prices on the import side defined in national currency, that is, excluding exchange rate movements, obtained from the same Eurosystem database. As our baseline pricing level, we use the Harmonised Index of Consumer Prices for all goods and services (HICP). We further compute exchange rate pass through estimates for core inflation estimated as either HICP excluding energy or HICP excluding energy and food, as well as for HICP goods and HICP services separately. We then subsequently delve deeper into the exchange rate pass-through estimates to the subcomponents making up the HICP goods index, that is Industrial Goods (decomposed into energy and non-energy industrial goods) and food. All consumer price indices are sourced from Eurostat. We use the percentage difference between actual and potential output (the Output Gap) as estimated internally by the Central Bank of Malta as our baseline measure for slack.[3] HICP indices as well as the index of foreign prices and oil prices are seasonally adjusted using the Census X12 procedure.

4 Results

4.1 Linear ERPT to consumer prices

In this section we present linear ERPT estimates. Figure 4 shows the estimated ERPT to overall (headline HICP) prices together with the 95% confidence bands. Results imply that ERPT is statistically significant at forecast horizons of one to three quarters after impact. Being insignificant on impact, our point estimate of ERPT increases progressively up to an absolute value of 0.22, or 22%, one year after the shock. However, the estimated coefficient diminishes slightly thereafter and is no longer statistically significant at the conventional 5% level. This result is consistent with the common findings in the literature that ERPT is incomplete, and that pass-through to consumer prices tends to be low. That said, the coefficients above are slightly higher than those found in the literature surveyed. Indeed, results show a stronger estimate for the peak ERPT than those found in Colavecchio and Rubene (2020), with the latter estimating a peak range of pass-through at 13% for the euro area.

We take a deeper look at the main drivers of these results by analysing ERPT to subcomponents of overall HICP. As a first step, we disaggregate overall HICP into goods and services prices. Our results show that

[3] Potential output is estimated using a Cobb-Douglas approach

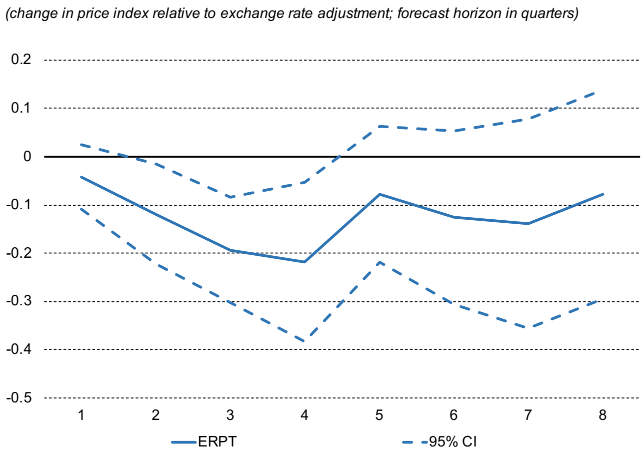

Figure 3: ERPT to headline HICP. *Source: Authors' Calculations.*

pass-through to goods prices is significantly larger than that to services prices. This is in line with expectations given that import content of services consumption is by its nature much lower than that for goods. We find ERPT to goods prices to be statistically significant at all forecast horizons except on impact, with the effect beyond one year after the shock being estimated at close to 40%. ERPT to services prices is, to the contrary, insignificant throughout except at a horizon of two quarters. This result is likely driven by the significantly low import content of consumer services that fall under the recreation and personal care (including the accommodation and catering services subindices), which in turn makes up around 54% of the HICP services subindex. Price dynamics of these consumer services are mainly driven by changes in wages, and thus are more dependent on the local labour market developments. These patterns tie in with the path of overall ERPT, which is strongest at the horizons where ERPT to goods and services prices are cumulatively relatively larger. Subsequently, the aggregate measure declines at later horizons, despite the continued strength of ERPT to goods prices, as that to service prices turns highly insignificant with its point estimates inverting sign. The finding that pass-through to goods prices is prolonged and significant up to two years following an exchange rate adjustment is particularly noteworthy, since it is an effect which is masked when analysing the effect on aggregate prices. The projected paths of ERPT to goods and services prices are shown in Figure 4 below.

In terms of pass-through to core inflation, we find markedly weaker results when compared to the specification using overall or headline HICP. In fact, as shown in Figure 5 below, we find no significant pass-through at any horizon when our dependent variable is HICP exclud-

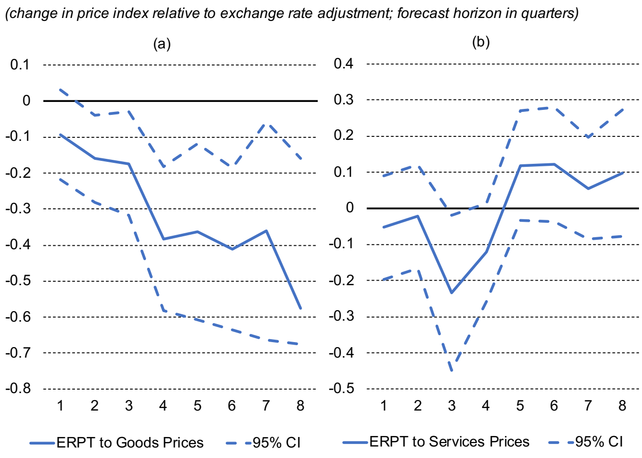

Figure 4: ERPT to goods and services prices. *Source: Authors' Calculations.*

ing energy, whilst when we regress HICP excluding energy and food, the relevant coefficient is only significant two quarters after impact. One implication of this outcome could be that our initial finding is somewhat driven by the behaviour of the energy and food components.

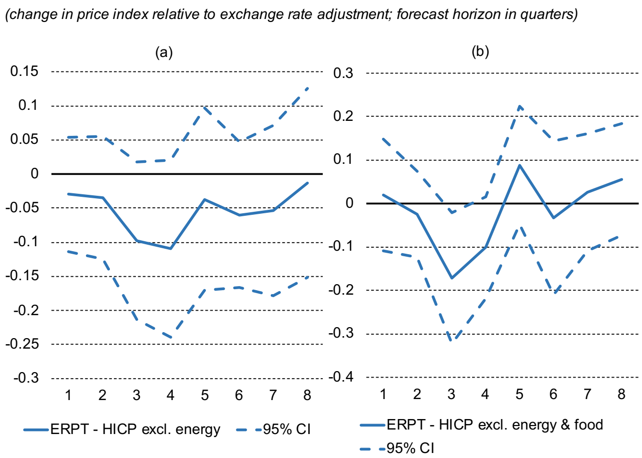

Figure 5: ERPT to core inflation. *Source: Authors' Calculations.*

This is confirmed following a deeper analysis of the HICP goods sub-index which can be decomposed into Industrial Goods and Food subcomponents. Results depicted in Figure 6 show that both sub-indices have significant pass-through of exchange rate fluctuations. Results for the food sub-index are statistically insignificant for the first year following changes in the exchange rate with very subdued point estimates. From the second year onwards however, exchange rate shocks lead to considerable and statistically significant pass-through to food prices in Malta.

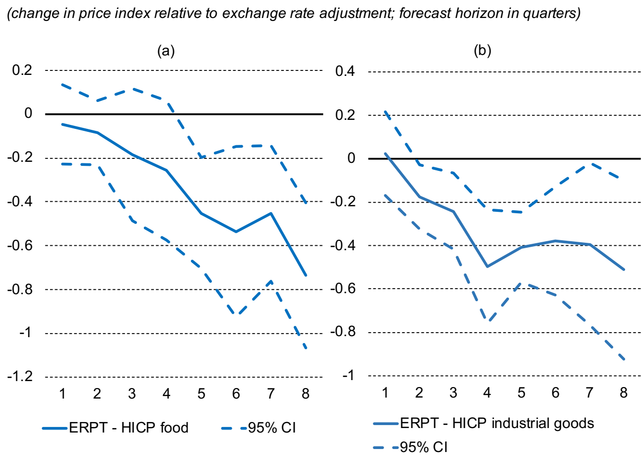

Figure 6: ERPT to goods subcomponents. *Source: Authors' Calculations.*

Industrial goods results feature a similar profile, with pass-through on impact being statistically insignificant before turning considerably negative between the second and fourth quarter in consideration. Looking more closely at industrial goods inflation in Figure 7, we can see that this profile is nearly wholly driven by developments in the energy subcomponent with the non-energy industrial good subcomponent featuring some weakly significant results only at around a year after the initial shock. This result is interesting on two grounds. Firstly, despite the fact that the vast majority of non-energy industrial goods in Malta are imported, exchange rate pass-through estimates for the non-energy industrial goods subcomponent are fairly low. This result is not surprising when looking at Direction of Trade (DoT) statistics. Indeed, one can note that only half of manufactured goods (SITC categories 5-8, making up around 98% of non-energy non-food imports in Malta) are imported from outside the euro area. Moreover, out of these, 60% are invoiced in euro implying that at a maximum of 20% of imported manufactured goods are exposed to currency fluctuations. Moreover, one needs to keep in mind that DoT data covers a more comprehensive subset of goods than that entering the non-energy industrial goods HICP basket. In fact, while the latter includes only finished consumer goods, trade data also includes semi-finished manufacturing products (such as production of semi-conductors) which have a greater tendency to be invoiced in US dollars. Moreover, such semi-finished goods are usually part of Global Value Chains, a factor which has been shown by literature to considerably reduce exchange rate pass-through. In this light, the non-energy industrial goods HICP sub-index might be in fact covering a basket of goods which is even less exposed to exchange rate fluctuations than suggested by the above direction of trade figures.

Secondly, energy prices feature considerable exchange rate pass-through despite the fact that currently energy prices are largely administered by Government. From 2014 onwards, in a bid to offer greater stability to energy prices and reduce uncertainty surrounding the price of fuels and electricity, the Government has significantly reduced the frequency of energy price adjustments. This has culminated in a policy of annual adjustments in energy prices that took place between 2016 and 2019. Still, the results shown in Figure 7 need to be interpreted while taking into consideration that for a substantial part of the estimation sample, energy prices in Malta (while still being largely administered by Government) were still experiencing fluctuations. For instance, between 2008 and 2013, energy prices in Malta were adjusted on a monthly frequency. Moreover, despite the greater element of price stability that ensued in 2014 and 2015, energy prices still featured some intra-year changes that roughly occurred at a quarterly frequency.

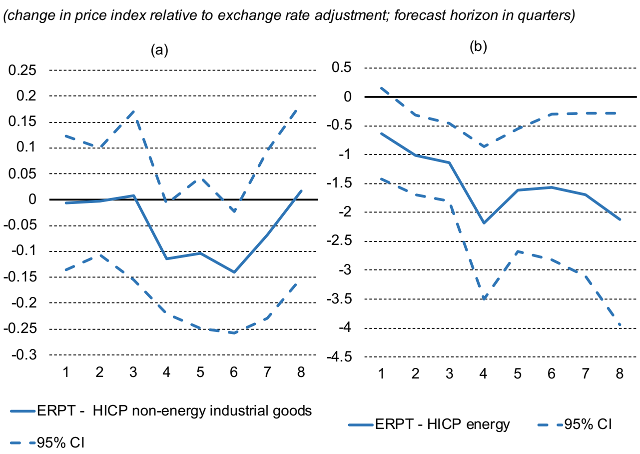

Figure 7: ERPT to industrial goods subcomponents. *Source: Authors' Calculations.*

4.2 Testing for non-linearities

Following the estimation of linear ERPT, we augment our model with relevant indicator variables to test for sign and size non-linearities.[4] We define an indicator variable, δ_t, which takes state-dependent values as follows. In the case of sign non-linearity:

$$\delta_t = \begin{cases} 1 & \text{if the exchange rate appreciates} \\ 0 & \text{otherwise.} \end{cases}$$

Meanwhile, when testing for size non-linearity, we specify:

$$\delta_t = \begin{cases} 1 & \text{if the exchange rate adjustment is large} \\ 0 & \text{otherwise.} \end{cases}$$

Meanwhile, when testing for size non-linearity, we define a change in the exchange rate to be 'large' if the absolute value of the change in e_t in a given period exceeds one standard deviation of the series of Δe_t over the sample, in line with Colavecchio and Rubene (2020).[5] Once again, Δe_t denotes the quarter-on-quarter change in the log of the NEER index.

We include the indicator variables in our model as follows:

$$p_{t+h} - p_{t-1} = \alpha(h) + \phi_0(h)[(1-\delta_t)\Delta e_t] + \phi_1(h)[\delta_t \Delta e_t] + \sum_{i=0}^{k} \mathbf{x}'_{t-i}(h)\gamma_i(h) + u_{t+h}(h)$$

Therefore, our non-linear model yields separate estimates of ERPT depending on the value of δ_t. Specifically, $\phi(h)$ yields the estimate of ERPT at each horizon h when the exchange rate depreciates (if testing for sign non-linearity) or when the change in the exchange rate is 'small' (if testing for size non-linearity), while $\phi_1(h)$ accordingly yields ERPT when the exchange rate appreciates or when the change is 'large'. This permits us to obtain separate IRFs for each state pertaining to each value of the binary indicator δ_t.

In terms of sign non-linearity, our results indicate that higher pass-through is observed in episodes of exchange rate depreciation, compared with appreciations. As seen in the left-hand panel of Figure 8, the coefficient for appreciations is statistically insignificant at all horizons, whilst that for depreciation episodes is significant from one quarter after impact to one year after the shock. The projected path of ERPT for depreciations follows a similar pattern to overall pass-through and its coefficient is, as expected, notably higher than that of the aggregate measure, which is dampened by the negligible effect

[4] Sign non-linearity refers to a context where the magnitude and the dynamics of ERPT differ according to whether the exchange rate change in question is an appreciation or a depreciation, while if ERPT varies depending on whether the magnitude of the exchange rate adjustment is large or small, this is referred to as size non-linearity.

[5] Nevertheless, following from the absence of a clear theoretical definition as to what constitutes a 'large' change, we employ different definitions in subsequent sensitivity analysis. Results are not sensitive to changes in the definition of a 'large' change in the exchange rate.

of appreciation episodes. Pass-through for depreciation episodes is in fact estimated to be in excess of 40% at its highest, four quarters after the shock, while overall ERPT peaks at around 22% in the same quarter. As noted in the literature review, results for sign non-linearity in the literature tend to exhibit heterogeneity between countries, yet greater pass-through for depreciations is a relatively more common finding.

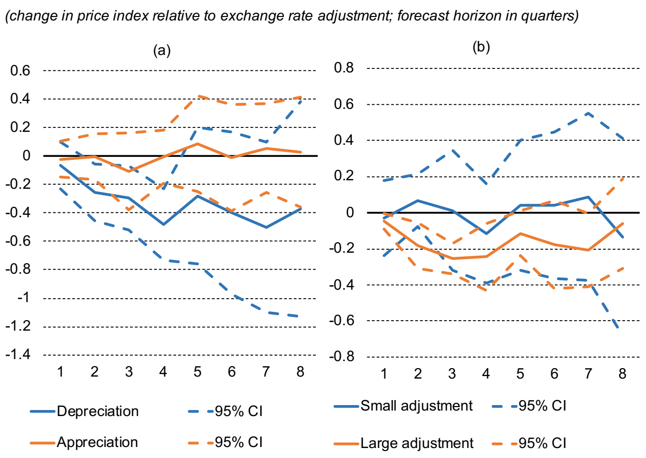

Figure 8: ERPT allowing for sign and size non-linearities. *Source: Authors' Calculations.*

Our results on size non-linearity are also in line with much of the literature, in that we find that large exchange rate changes are passed through to a greater extent than relatively small changes. No significant ERPT is found for small changes at all projected horizons, whilst large changes show a relatively stable pass-through which is significant up to the one-year horizon. With the exception of the impact time period and the subsequent quarter, pass-through in such instances exceeds 20%.

5 Conclusions

Exchange rate pass-through is a key metric in gauging the relationship between exchange rate adjustments and prices in an economy. ERPT estimates have several uses, not least in gauging market conditions, inflation forecasting and as an input to monetary policy decisions. This paper uses Jordà (2005) local projections to estimate ERPT to consumer prices in Malta post- euro adoption, accounting for linear and non-linear ERPT to overall consumer prices as well as to a number of price sub-indices.

The results we obtain can be summarised as follows. Estimating ERPT to headline HICP prices, we indeed find relatively high ERPT in the shorter-term horizon, which however tapers off after a year. In general, therefore, changes in currency exchange rates are reflected in local prices for up to a year after they occur; for every 1% change in the NEER, prices change by close to 0.25% in the twelve months that follow. Nevertheless, this aggregate estimate seemingly conceals deeper heterogeneity in the transmission of exchange rate shocks to consumer prices, which is uncovered when estimating pass-through to core inflation and to goods and services prices, and also when allowing for non-linear responses to the size and direction of the exchange rate adjustment. We note that pass-through to core inflation is relatively weaker than that to overall prices, whilst as expected, we find that pass-through to goods prices is the main driving force behind overall ERPT. Passthrough to goods prices also results to be more persistent over time: exchange rate changes feed through to prices after one quarter and remain relevant even up to two years after the change. In turn, pass-through to goods prices is driven by energy, whose prices were frequently adjusted over the first half of the sample. Similarly, it results that it is mainly episodes of depreciation and changes of a relatively larger magnitude that are transmitted into inflation, with effects mostly sustained over an eight-quarter forecast horizon, whilst effects for appreciations and small changes are negligible. Our results are also mostly consistent with theory and with the empirical literature for euro area countries.

This paper therefore provides an initial set of reduced-form ERPT estimates for the Maltese economy using a robust methodology and accounting for changes in the monetary regime. In so doing, our work also serves as a benchmark for the calibration and estimation of macroeconomic models of the Maltese economy. Future studies can build upon this work by delving into ERPT to import prices, and also potentially exploring methodologies to obtain a longer time series of estimates. Lastly, in line with the latest developments in the literature, future studies can employ structural models to explore the prevalence and characteristics of shock-dependence in ERPT in the Maltese economy. Using these structural models, it would be of interest to consider the structural role of exchange rate shocks in the current inflationary environment.

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