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## Shock dependence of exchange rate pass-through: a comparative analysis of BVARs and DSGEs

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### Abstract

In this paper, we make use of the results from Structural Bayesian VARs taken from several studies for the euro area, which apply the idea of a shock-dependent Exchange Rate Pass-Through, drawing a comparison across models and also with respect to available DSGEs. On impact, the results are similar across Structural Bayesian VARs. At longer horizons, the magnitude in DSGEs increases because of the endogenous response of monetary policy and other variables. In BVARs particularly, shocks contribute relatively little to observed changes in the exchange rate and in HICP. This points to a key role of systematic factors, which are not captured by the historical shock decomposition. However, in the APP announcement period, we do see demand and exogenous exchange rate shocks contribute significantly to variations in exchange rates. Nonetheless, it is difficult to find a robust characterization across models. Moreover, the modelling challenges increase when looking at individual countries, because exchange rate and monetary policy shocks (also taken relative to the US) are common to the whole euro area. Hence, we provide a local projection exercise with common euro area shocks, identified in euro area-specific Structural Bayesian VARs and in DSGE, extrapolated and used as regressors. For common exchange rate shocks, the impact on consumer prices is the largest in some new member states, but there are a wide range of estimates across models. For core consumer prices, the coefficients are smaller. Regarding common relative monetary policy shocks, the impact is larger than for exchange rate shocks in any case. Generally, euro area monetary policy plays a big role for consumer prices, and this is especially so for new member states and the euro area periphery.

**Keywords**

euro area, exchange rate pass-through, Bayesian VAR, local projections, monetary policy

**JEL Classification**

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# Shock dependence of exchange rate pass-through: a comparative analysis of BVARs and DSGEs

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## ABSTRACT

In this paper, we make use of the results from Structural Bayesian VARs taken from several studies for the euro area, which apply the idea of a shock-dependent Exchange Rate Pass-Through, drawing a comparison across models and also with respect to available DSGEs. On impact, the results are similar across Structural Bayesian VARs. At longer horizons, the magnitude in DSGEs increases because of the endogenous response of monetary policy and other variables. In BVARs particularly, shocks contribute relatively little to observed changes in the exchange rate and in HICP. This points to a key role of systematic factors, which are not captured by the historical shock decomposition. However, in the APP announcement period, we do see demand and exogenous exchange rate shocks contribute significantly to variations in exchange rates. Nonetheless, it is difficult to find a robust characterization across models. Moreover, the modelling challenges increase when looking at individual countries, because exchange rate and monetary policy shocks (also taken relative to the US) are common to the whole euro area. Hence, we provide a local projection exercise with common euro area shocks, identified in euro area-specific Structural Bayesian VARs and in DSGE, extrapolated and used as regressors. For common exchange rate shocks, the impact on consumer prices is the largest in some new member states, but there are a wide range of estimates across models. For core consumer prices, the coefficients are smaller. Regarding common relative monetary policy shocks, the impact is larger than for exchange rate shocks in any case. Generally, euro area monetary policy plays a big role for consumer prices, and this is especially so for new member states and the euro area periphery.

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<sup>4</sup> This paper is based and extends Section 5 of Ortega and Osbat (eds.) (2020) and it was developed while the author was on secondment at the ECB. The conclusions expressed in the paper are those of the author and do not necessarily represent the official views of the Bank of Lithuania, the ECB or of the ESCB.

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## Executive summary

The concept of the shock dependency of the pass-through emerged from an understanding that exchange rate movements can have different effects on prices. Reduced form estimates using macro data can yield a useful rule of thumb for import prices, although better estimates of pricing equations can be obtained from micro data when an instrument for identification is available. Highly complex mechanisms, as well as the limited availability and lack of richness of micro datasets on consumer prices as compared to those on trade prices, make it difficult to rely on rules of thumb to assess the impact of the exchange rate on consumer prices. While a simple reduced form estimate of ERPT may be informative for import prices, a more shock-dependent approach to assessing pass-through (i.e. the PERR) should be considered for HICP and its components.

In this paper, we made use of the results from BVARs in several studies for the euro area which apply the idea of a shock-dependent Exchange Rate Pass-Through (ERPT) or Price-to-Exchange Rate Ratio (PERR) covering a period from the 1990s to the most recent quarter available. We draw a comparison across models and also with respect to available DSGEs. The new shock-dependent ERPT, which is also called the Price-to-Exchange-Rate Ratio (PERR), as in Ortega and Osbat (eds.) (2020), is viewed not as a "transmission" of exchange rate changes, but as a "co-movement" of prices and exchange rates given different shocks. The data covers the period from 1999Q1 to 2019Q2.

On impact, the PERRs are similar across DSGEs and BVARs. At longer horizons, the PERRs in DSGEs increase because of the endogenous response of monetary policy and other variables. In general, we can conclude that different domestic and global shocks can be associated with widely different pass-throughs, and that country characteristics may matter. Overall, in BVARs especially, the shocks contribute relatively little to observed changes in the exchange rate and in HICP over time, pointing to a key contribution of systematic factors, which have not been captured by the historical shock decomposition. We find a similar outcome looking at 2018 data, while in the case of the APP announcement, both demand shocks and exogenous exchange rate shocks seem to have contributed.

The modelling challenges increase when looking at individual countries, because exchange rate and (relative to the US) monetary policy shocks are mostly common to the whole euro area in the considered time span and cannot be fully identified using data from only one country. Therefore, we provide here also country-specific results by applying local projections and common shocks extracted from the BVARs and the NBB DSGE. For common exchange rate shocks (also taken relative to the US), the impact on consumer prices is the largest in some new member states, but there is a wide range of estimates across models. For core consumer prices, the coefficients are even smaller. The very low values in core consumer prices can be mostly attributed to the price of services in case of exchange rate shocks for the BVARs. For common relative monetary policy shocks, the impact is larger, and this even more true in some periphery countries. Generally speaking, euro area monetary policy plays a bigger role for consumer prices, and this is especially so for new member states and the euro area periphery.

## 1. INTRODUCTION

In this paper, we investigate the pass-through of exchange rate to prices and its dependence on different shocks in the euro area. We compare the outcomes from Structural Bayesian VARs (BVARs) and DSGEs, and provide country-specific results by applying local projections and common shocks extracted from the BVARs.

The idea of the shock dependency of the pass-through emerged from the understanding that exchange rate movements can have different effects on prices. The underlying reasons for a shock-dependence of ERPT are many. For example, price setters may react differently to exchange rate movements triggered by different economic shocks. Or, when the exchange rate is predominantly determined by demand shocks that presumably appreciate the exchange rate, ERPT estimates may be of a theoretically unexpected sign. These simple arguments support the possibility that ERPT may in fact depend on the shock that triggers the exchange rate movements - a feature often overlooked in empirical analyses of ERPT.

Overall, reduced form estimates using macro data can yield a rule of thumb of some utility for import prices, although better estimates of pricing equations can be obtained from micro data when an instrument for identification is available. It is much harder to rely on rules of thumb for the impact of the exchange rate on consumer prices, because of more complex mechanisms but also because micro datasets on consumer prices are less available and usually less rich than those for trade prices. Overall, while a simple reduced form estimate of ERPT may be informative for import prices, a more shock-dependent approach to assessing pass-through (i.e. the PERR) ought to be considered for HICP and its components.

In this paper, we make use of results from BVARs taken from several studies which apply the idea of a shock-dependent Exchange Rate Pass-Through (ERPT) or Price-to-Exchange Rate Ratio (PERR) covering a period from the 1990s to the most recent quarter available. This allows us to analyse a combination of several identifications and specifications. We then draw comparisons across models and also with respect to available DSGEs.<sup>5</sup>

On impact, Price-to-Exchange Rate Ratios are similar across DSGEs and BVARs. At longer horizons, the PERRs in DSGEs increase because of the endogenous response of monetary policy and other variables. In general, we can conclude that different domestic and global shocks can be associated with widely different pass-throughs, and that country characteristics may matter.

Yet it is difficult to find a robust characterization across models of the configuration of shocks that drive the exchange rates and prices. The modelling challenges increase when looking at individual countries, because exchange rate and (relative to the US) monetary policy shocks are mostly common to the whole euro area in the considered time span and cannot be fully identified using data from only one country. This is the reason why we provide a local projection exercise with common euro area shocks, identified in euro area-specific BVARs, extrapolated and used as regressors (or instruments as in Lane and Stracca, 2018). Moreover, we provide the responses of prices by using the estimated shocks for the past in the NBB DSGE case. For common exchange rate shocks (also taken relative to the US), the impact on consumer prices is the largest in some new member states, but there is a wide range of estimates across models. In any case, this found

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<sup>5</sup> We collected the common set of data and asked the remaining authors to run their codes for BVARs and DSGEs (for CK and Forbes setups, we ran the BVARs ourselves). Therefore, we received from them the raw results only. All the further calculations, comparison and homogenization done in the paper are our work only (this includes local projections and time-varying measures as well). Section 9.2 uses the outcomes from a version of Leiva et al. (2020) with data up to 2018Q4.

heterogeneity across member states is strongly in line with the recent literature (Lane and Stracca, 2018). For core consumer prices, the coefficients are even smaller. This is because of low pass-through to price of services in BVARs. For common relative monetary policy shocks, the impact is larger both in BVARs and DSGE. Generally, euro area monetary policy plays a bigger role for consumer prices compared to exogenous exchange rate shocks, and especially so for new member states and euro area periphery. The very low values in core consumer prices can be mostly attributed to the price of both services and non-energy industrial goods.

In Section 2, we describe the strand of literature related to shock dependency of the pass-through; Section 3 briefly clarifies the different definitions of pass-through for readers' convenience. Section 4 looks at the different BVARs and their identification and Section 5 describes the local projections. Following this, Section 6 lists the data and sources. Section 7 provides a comparison between BVARs and DSGEs in identifications, PERRs and historical decompositions. Section 8 analyses the country-by-country results by applying local projections. Section 9 looks at possible time variation in shock-dependent ERPTs and Section 10 concludes.

## 2. BRIEF LITERATURE REVIEW ON SHOCK-DEPENDENT PASS-THROUGH

The notion of the shock dependency of the pass-through is based on the understanding that exchange rate movements can have different effects on prices. This point was applied for and by policy makers almost a decade after the seminal academic contribution by Corsetti and Dedola (2005), when K. Forbes, then a board member of the Bank of England, noted that, *using rules of thumb for exchange rate pass-through could be misleading*.<sup>6</sup> Generally speaking, the rule of thumb from reduced form estimations in a macroeconomic setup can be of some guidance only in case of import prices, where this comes from pricing equations. Regarding consumer prices, this is less clear due to the process of price aggregation. In a nutshell, a simple Exchange Rate Pass-Through (ERPT) may be informative for import prices, while a more shock-dependent pass-through should be considered for HICP and its components. There is a strong assumption that the exchange rate is governed by exogenous shocks only to itself. This assumption has been challenged in some more theoretical contributions (see Corsetti and Dedola, 2008), but only recently applied in the empirical measures of ERPT. These studies aimed at developing shock-dependent ERPTs, as shown in Shambaugh (2008) and Forbes et al. (2018; 2017), Comunale and Kunovac (2017) and An et al. (2020) for Japan, all using BVARs, and Ha et al. (2019) using a structural factor-augmented vector-autoregressive model.

Shambaugh (2008) suggests that the ERPT ratios to consumer inflation do not react to all shocks in the same way, and that demand shocks are of limited importance for pass-through. Import prices move in the same direction as the exchange rate after every shock, except for one in foreign prices.<sup>7</sup> Forbes et al. (2018) and (2017) confirms that the domestic monetary policy shock is related with a large ERPT to consumer prices both in the UK and in a sample of advanced and emerging economies as well, with a much smaller pass-through found for domestic demand shocks. Comunale and Kunovac (2017), in an analysis for the euro area and four major economies, find that pass-through is the strongest when the exchange rate movement is triggered by

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<sup>6</sup> This is the title of a Vox.EU column by K. Forbes, I. Hjortso and T. Nenova of 12 February 2016: <https://voxeu.org/article/using-rules-thumb-exchange-rate-pass-through-could-be-misleading>

<sup>7</sup> The author looks at the results for Germany, as a euro area member state, for the period 1973Q1-1999Q4 and for the shock-dependent ERPT to consumer prices only (ERPT=0.37). He does not analyse the euro area as a whole.



(relative) monetary policy shocks and also by exogenous exchange rate shocks. In the latter, the pass-throughs are not constant over time - they may depend on a composition of economic shocks governing the exchange rate. The time-varying ERPT are then be obtained as ratios between cumulated impulse response functions (IRFs) of prices and of exchange rates following a particular shock, weighted by the importance of the same shock in the historical decomposition of the exchange rate (Comunale and Kunovac, 2017). A different type of identification is then used in An et al. (2020) for Japan, where the shocks are identified in the BVAR by complementing the traditional sign and zero restrictions (based on Forbes et al., 2018) with informative narrative sign restrictions related to the Plaza Accord (single event happened in October 1985).<sup>8</sup> The authors confirm the difference in the ERPT depending on different shocks, with the exogenous exchange rate shock being the most important driver for Japan. Most recently Ha et al. (2019) extends the sample, providing a structural factor-augmented vector-autoregressive model for 47 countries, accounting for the nature of the shocks and country-specific characteristics. The results are in line with the studies listed above: different shocks can be associated with different pass-through measures, and country characteristics may matter.

Lastly, Lane and Stracca (2018) measure the effects of real effective exchange rate (REER) movements on macroeconomic variables of interest by using the local projections method by Jordà (2005), combined with the instrumental variables (IVs) technique. The authors provide a monthly VAR (estimated in a frequentist way) for the euro area and identify, via sign restrictions, four shocks: demand, supply, monetary policy, and foreign FX shock. These will be then used as an instrument.<sup>9</sup> The authors thus assume that the euro can appreciate for reasons that are independent of country characteristics, and therefore that the shocks are exogenous. This will also be our rationale in using local projections for our country-by-country exercise for euro NEER shocks to prices in the member states. Lane and Stracca (2018) conclude that there is an evident heterogeneity in how the euro exchange rates transmit to member states and an appreciation has a prevalent expansionary effect in most countries.

### 3. DEFINITIONS OF PASS-THROUGH

This initial section aims to clarify the differences between the widely used definition of ERPT and the new shock-dependent ERPT or PERR (see also Ortega and Osbat (eds.), 2020). The largest branch of the literature focuses on a "structural" definition of ERPT arising from a pricing equation, in which the considered price index (or its growth rate) is regressed on the exchange rate and some control variables. Both in empirical single dynamic equations and in BVARs exchange rate, pass-through at any given horizon is defined as the impulse response of inflation to the exchange rate "shock". In single equations, this "shock" is not structurally identified but assumed to be exogenous by taking care not to have relevant omitted variables in the regression; in BVARs, it is identified using various schemes. Following Ortega and Osbat (eds.) (2020), we look at a simple pricing equation, in which the considered price index (or its growth rate) is regressed on the

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<sup>8</sup> The authors in An et al. (2020) impose a specific narrative sign restriction around October 1985, after the Plaza Accord was signed. The exchange rate shock is a yen-appreciation shock. The latter also contributes more to the variation of the Japanese Exchange rate compared to other shocks around that time.

<sup>9</sup> They apply, as for a first set of instruments for the variation in the country-specific REER ( $t$ ), the variation in the euro NEER ( $t$ ) interacted with the share of country exports to outside the euro area ( $t-1$ ). See Lane and Stracca (2018) for more details.

exchange rate and some control variables. In macroeconomic studies, the impact of exchange rate changes on the aggregate inflation is investigated by using a distributed lag equation as below:

$$\Delta p_t^z = \alpha + \sum_{k=0}^K \beta_k \Delta s_{t-k} + \sum_{r=1}^{K_r} \gamma_r x_{rt-k} + \varepsilon_t \text{ with } z \in (F, Fr, C) \quad (1)$$

where  $s_t$  is the exchange rate (nominal effective or bilateral),  $x_{rt}$  are  $R$  control variables and  $K$  is the maximum lag length. This applies to any price: import, producer, consumer, or any other aggregate price.  $z \in (F, Fr, C)$  means that the prices in the equation can be either import prices at retail (Fr) or at the border (F) or consumer prices (C). Lags of the left-hand-side inflation variable can also be added as explanatory variables, giving rise to auto-regressive distributed lag specifications. The exchange rate pass-through at any horizon  $h$  will be measured by the (cumulative sum of) the coefficients of the exchange rate:

$$ERPT_h^z = \sum_{k=0}^h \beta_k \text{ where } z \in (F, Fr, C) \quad (2)$$

The new shock-dependent ERPT, which is also called Price-to-Exchange-Rate Ratio (PERR), as in Ortega and Osbat (eds.) (2020), is seen not as "transmission" of exchange rate changes, but as "co-movement" of prices and exchange rates given different shocks as in the following equation:

$$PERR_{j,h}^z = \frac{\sum_{t=1}^h IRF_j(\Delta p_t^z)}{\sum_{t=1}^h IRF_j(\Delta s_t^z)} = \frac{IRF_j(p_t^z)}{IRF_j(s_t^z)} \text{ where } z \in (F, Fr, C) \quad (3)$$

This measure reflects the correlation between the exchange rate and inflation, conditional on each of the identified shocks and serving as a shock-dependent ERPT measure/PERR. We take the ratios of the cumulative sum of net changes of the IRFs of inflation to each of the shocks over the cumulative sum of net changes of the IRFs of exchange rate changes (q-o-q) to the same shock. Here, all shocks are inflationary and an increase means appreciation.

Both ERPT and PERR measures are useful to assess the relationship between exchange rates and prices, and they complement each other. The "rule of thumb" from reduced form estimations in a macroeconomic setup can be of some guidance only in case of import prices, where this comes from pricing equations. As for consumer prices, this is less clear due to the process of price aggregation. In a nutshell, a simple ERPT may be informative for import prices, while a more shock-dependent pass-through should be rather considered for HICP and its components.

The shock-dependent approach however, is far from straightforward; it is hard to find a robust characterization across models of the configuration of shocks that drive the exchange rates and prices especially for one country at any point in time. Given this difficulty, we add a local projection exercise using identified common shocks to the euro area (monetary policy and exogenous exchange rate shocks), looking at how consumer prices and components react. This is a way to circumvent the drawbacks of country-by-country BVARs for the euro area countries and therefore, in the end, the response of prices still depends on identified shocks.



## 4. DIFFERENT BVARs AND THEIR IDENTIFICATIONS

### 4.1. Description of the BVARs

We include available results from BVARs taken from several studies which apply the idea of a “shock-dependent ERPT” (also called here PERR).<sup>10</sup> The dataset used is the same for all the BVARs and covers a period from the 1990s to the most recent quarter available (2019Q1).<sup>11,12</sup> The BVARs considered all rely on the same method of identifying shocks: by using sign and zero restrictions. This imposes parsimony on the models, but it is not possible to build a comprehensive model featuring all the shocks we would be interested in (not least for computational reasons). All the papers assume independent Normal Inverse-Wishart priors.

Thus, the models differ only in terms of the variables considered and the set of shocks that they are able to identify. Only some, i.e. Comunale and Kunovac (2017) and Forbes et al. (2018)<sup>13</sup>, include import prices, but the former uses relative monetary policy of the euro area with respect to the US,<sup>14</sup> while the latter includes only the euro area monetary policy. Conti et al. (2017) also consider both monetary policies; however, the US policy is considered exogenous.<sup>15</sup> Lastly, Leiva et al. (2020) use a measure of relative monetary policy (and relative GDP) but do not include import prices in the model.<sup>16</sup> The BVARs also differ in terms of the exchange rate considered. The exchange rate is either the bilateral EUR/USD rate (in Conti et al. (2017); Leiva et al. (2020)) or broad NEER (Conti et al. (2017); Forbes et al. (2018) and Comunale and Kunovac (2017)). The import prices, when included, are taken as the total of the extra- and intra-euro area. The results for only extra-euro area import prices are much less robust in terms of PERRs, especially for domestic demand and supply shocks, while FX and MP shocks are more in line with expectations and hence also bigger than the PERRs for the total import prices.<sup>17</sup>

These papers also apply different identification schemes, as shown in Table 1. We take into consideration four common shocks across models, namely, an exogenous exchange rate shock, domestic demand and supply shocks, and a monetary policy shock, in the spirit of Lane and Stracca (2018). We then transform the identified shocks in order to ensure an increase in FX as appreciation in our results.

[Insert Table 1 here]

### 4.2. DSGEs at a glance

Structural DSGE models allow us to study ERPTs and PERRs using the structural determinants of the pricing equations as well as the endogenous response of the economy in a general equilibrium context. The DSGEs

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<sup>10</sup> For the time being, we do not consider the identification as in Lane and Stracca (2018) for two main reasons. The first one is that in this contribution the authors do not use the VAR to compute shock-dependent ERPTs/PERRs, but rather make use of the shocks only in the local projection exercise as alternative IVs. Secondly, their VAR is not Bayesian and is at monthly frequency, and they use different variables to identify the shocks. They use industrial production instead of real GDP and they do not consider unconventional monetary stance, by having shadow rates (i.e. they use the 3-month Euribor rate). They do not impose any restriction on the reaction of industrial production to FX shocks, because the main question addressed in their paper is indeed whether these shocks are expansionary or contractionary.

<sup>11</sup> For the BVAR in Montes-Galdon et al. (2019), the data end in 2017Q4. We will not include this approach in the main charts/tables of the paper, using it only as an interesting check due to the fact that this is the only BVAR including both EA and US monetary policy as endogenous. However, its inclusion with all the data up to 2017Q4 does not alter the final conclusions of the paper.

<sup>12</sup> We perform the same exercise with data up to 2017Q4 or 2018Q2 and the results are very robust (available upon request).

<sup>13</sup> Forbes et al. (2018) is here used only as a robustness check and their identification is applied for the euro area case. As a result, it is important to note that the results for the euro area reported here are not directly taken from Forbes et al. (2018).

<sup>14</sup> There could be issues with using relative monetary policy shocks; see, for evidence of FED and ECB asymmetries, Jarocinski and Karadi (2018).

<sup>15</sup> The model in Montes-Galdon et al. (2019), only used as a check (see footnote 10), instead distinguishes euro area and US monetary policy shocks, treating them both endogenously, but for parsimony dictated mostly by computational limitations, it does not include import prices. The exchange rate in their model is the bilateral EUR/USD.

<sup>16</sup> This BVAR model has been also augmented with exogenous oil prices (BVAR-X approach).

<sup>17</sup> This set of results is available upon request.

can be taken as a guide for the BVARs, as their sequencing is clear, for both the signs and the timing of the identification restrictions.

In this paper, we look at 7 DSGEs for the aggregate euro area taken from Ortega and Osbat (eds.) (2020) and Pisani (2019). The Bank of Finland, Bank of Italy, Deutsche Bundesbank, De Nederlandsche Bank, ECB, National Bank of Belgium (NBB), and National Bank of Romania provided their models of the euro area. All models are New Keynesian, i.e., based on nominal (price and/or wage) rigidities. Monetary policy, modelled by a Taylor rule on the short-term policy rate, has a non-trivial stabilization role. As reported in Ortega and Osbat (eds.) (2020), models are taken to the quarterly data through calibration or estimation of key parameters. Therefore, they are able to provide not only a theory-consistent transmission mechanism, but also quantitative results. The simulation of multiple models, based on different specifications and values of parameters, allows us to obtain cross-model robust results.

As for the PERR, we will consider the medians of the results across DSGEs, given the heterogeneity across models. We look at shock-dependent ERPTs from the DSGEs in the same fashion as for the BVARs, with the same set of shocks, and where the exogenous FX shock is the UIP shock. This is further analysed in Ortega and Osbat (eds.) (2020) and Pisani (2019). As for the identification scheme and for the historical decompositions instead, we focus on NBB DSGE (see De Walque et al., 2017, 2019), which is rich in terms of features (LCP, distribution sector, intermediate goods in the production function) and the closest to a comparison with our BVARs. NBB DSGE (see De Walque et al., 2017, 2019) is a two-country DSGE including the US and EA,<sup>18</sup> with an open economy block and estimated by Bayesian full-info ML approach (Smets and Wouters, (2007)) fixing some parameters if poorly identified (priors). The other 6 DSGEs are calibrated or estimated and they do not have the same characteristics, which makes the NBB the best candidate among all of them for drawing some meaningful comparisons with BVARs.

## 5. LOCAL PROJECTIONS

We want to assess how HICP, its components (including HICPX, i.e. core HICP) and import prices react to EA common shocks identified via BVARs, i.e. euro exchange rate shock or monetary policy shock. In this case, we used several common shocks coming from this strand of the literature (see Ortega and Osbat (eds.), 2020). In order to do so, we make use of a local projection exercise à la Jordà (2005).

Recently, a similar idea/approach was used for potential output and demand/supply shocks in Coibion et al. (2018) and Gorodnichenko and Lee (2017) for TFP shocks and monetary policy shocks. In the local projections, the shocks are directly used, rather than the original series (shadow rates or NEER in our case). This is because we are interested in the dynamic responses of inflation and GDP growth to structural shocks, previously identified. As noted in Gorodnichenko and Lee (2017), this is normally done by using Structural VARs or DSGEs to construct the responses. However, focusing on single shocks and single equation methods to compute them, as in the local projections, helps when the structural shocks cannot be well-identified. As reported by Brugnolini (2018), if a Structural VAR cannot be well-specified and/or the sample size is small, the local projections can provide a valid alternative for computing the impulse responses. Moreover, it allows other sources of variation to be unspecified, and imposes no restrictions on the shape of the impulse responses. In

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<sup>18</sup> Hence, in this case, the exchange rate is the bilateral EURUSD.

our baseline, the shocks and dependent variables appear without any lags, and we do not include any further controls. The local projection exercise is applied on HICP (and components) regressed on a constant and a shock.<sup>19</sup> Our idea is very close in spirit to the recent contribution by Lane and Stracca (2018), as reported in the literature review, where the authors provide a monthly VAR (estimated in a frequentist way) for the euro area and identify, via sign restrictions, four shocks: demand, supply, monetary policy, and foreign FX shock. The shock in FX is used as an instrument in the local projection equation.

In our local projection framework, more specifically, we have different inflation measures (y-o-y changes) as dependent variables for each country  $Y_t$ . In the regressors set we add the outcomes from common FX and monetary policy shocks  $\epsilon_{t,k}$ . The common monetary policy shocks can be of different types depending on which BVAR we consider. We can have a euro area monetary policy shock alone (following Forbes et al. (2018) or Conti et al. (2017)) and then a relative monetary policy shock à la Comunale and Kunovac (2017) or as in Leiva et al. (2020).<sup>20</sup> Moreover, Conti et al. (2017) defines only the euro area monetary policy as endogenous while the US monetary policy is taken as an exogenous variable.<sup>21</sup>

The BVARs also differ in terms of the exchange rate. The exchange rate is either the bilateral EUR/USD rate (in Leiva et al. (2020) or Conti et al. (2017)) or broad NEER (Conti et al. (2017); Forbes et al. (2018) and Comunale and Kunovac (2017)).

The shocks are taken in q-o-q variations, hence the possible changes in exchange rates and monetary policy in a quarter can play a role on how much the inflation rate y-o-y will be.

$$Y_t = \alpha + \phi_k \epsilon_{t,k} + \varepsilon_t \quad (4)$$

In the formula above,  $k$  refers to the shock (to exchange rate or monetary policy). The different  $\phi_k$  coefficients will be therefore country-specific.

We make use of the common euro area shocks coming from all the BVARs, and we summarise the results by showing medians and confidence bands across models. Therefore this approach looks at comparison across BVARs in the form of confidence bands' widths, in the case of the two shocks considered.<sup>22</sup> Moreover, we provide the responses of prices by using the estimated shocks for the past in the NBB DSGE case.<sup>23</sup>

## 6. DATA DESCRIPTION AND SOURCES

For this analysis, we used the following set of variables: real GDP (seasonally and working day adjusted);<sup>24</sup> HICP (seasonally and working day adjusted); country-specific competitor export prices weighted by country's import shares; and total import deflator. This last variable is extra- plus intra-EA for goods and services and

<sup>19</sup> The exercise has been also done running simple regressions (not with local projections) with monetary policy and exchange rate shocks added together, because they are orthogonal, with lags from 0 to 4. The results are comparable to the reported ones coming from local projections. The results are available in Appendix I.

<sup>20</sup> Both euro area and US monetary policy shock are considered in the Montes-Galdon et al. (2019) approach; however, we have data only until 2017Q4 in this case.

<sup>21</sup> These results come from an updated version of Conti et al. (2017). This setup includes the CISS (systemic stress indicator, EA).

<sup>22</sup> We look at FX and monetary policy shocks only because they are the only actual common shocks across euro area member states (following Lane and Stracca (2018)). The supply and demand shocks are only available for the aggregate EA and these cannot be common across members but somehow represent an aggregate of such. Therefore, they would not represent an idiosyncratic shock for the member states, which is the idea of demand and supply shock.

<sup>23</sup> As for the selected BVARs, the data for NBB DSGE shocks are until 2019Q1.

<sup>24</sup> In case of Leiva-Leon et al. (2018), the relative real GDP with respect to the US is also used.

extra-EA, country-specific broad Nominal Effective Exchange Rates (NEER) with import weights or bilateral EUR/USD exchange rate.

For the local projections, we also use the HICP components (core HICP, non-energy industrial goods price index, NEIG and services price index, SERV). These series are retrieved from ECB SDW or ECB internal sources (ECB projections database) and they are seasonally adjusted.

As for the interest rates, we used the shadow rates for the euro area and the US from Krippner (2016). In the current version, we replaced the shadow rates from Wu and Xia (2016) with the ones taken from Krippner (2016), as the latter have proven to be more consistent and comparable across conventional and unconventional monetary policy environments and are less subject to variation with modelling choices (see Comunale and Striaukas, 2017).<sup>25</sup>

We extended the datasets to the most recent quarter available, for comparability. Moreover, we transformed all the variables, except the interest rates, in q-o-q log differences. The data covers the period from 1999Q1 to 2019Q1 at quarterly frequency.

## 7. EURO AREA BVARs AND DSGES: A COMPARISON

### 7.1. Comparing the identifications

We report in Table 1 the original identifications for the four common shocks in the BVARs and in Table 2 the NBB DSGE identification from De Walque et al. (2017, 2019). Only afterwards, for comparability, we make all shocks inflationary and a FX increase will mean appreciation. Based on the models covered here, there are several similarities across BVARs and DSGEs, but also some discrepancies.

The identification schemes across the available BVARs (Table 1) are highly comparable and almost completely match (up to some unrestricted responses) those in the structural model NBB DSGE (Table 2).<sup>26</sup> The one that does not match is the impact of the domestic supply shock on inflation: in the BVARs there is a need to identify the supply from demand (a negative restriction is needed), but in the DSGE the effect is not different from zero and the opposite signs only appear and become reliable after three to four quarters.

[Insert Table 2 here]

### 7.2. The PERRs across setups

The comparison between the results for structural BVARs and structural DSGE models is reported in Table 3 for the shock-dependent ERPTs/PERRs to consumer prices and in Table 4 for import prices.

[Insert Table 3 and 4 here]

We take into consideration four common shocks across models, namely, an exogenous exchange rate shock, domestic demand and supply shocks and a monetary policy shock. The exchange rate shock can be based either on bilateral rate EUR/USD (in Conti et al. (2017); Leiva et al. (2020)) or broad NEER (in Conti et al. (2017); Forbes et al. (2018) or Comunale and Kunovac (2017)). As for monetary policy, we can refer to a

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<sup>25</sup> For a deep analysis of pros and cons of different shadow rates, refer to Comunale and Striaukas (2017).

<sup>26</sup> For the NBB DSGE, the shocks were initially grouped in different categories: UIP, EA and US monetary policy, EA aggregate demand, EA aggregate supply, and other shocks.

relative measure with respect to the US (Comunale and Kunovac (2017) and Leiva et al. (2020)) or to the euro area only (Conti et al. (2017); Forbes et al. (2018)).<sup>27</sup> We report in the tables the medians of (different) BVARs and of the overall DSGE models. It is important to note that Forbes et al. (2018) is here used only as a robustness check. We basically applied the same identification as in this study for the euro data case. Hence, the related results are based on that and do *not* come directly from Forbes et al. (2018).

As in the literature, the ERPT declines along the pricing chain, in both BVARs and DSGE models. Overall, the dynamics of the impacts are bigger and more persistent in DSGEs compared to the BVARs considered. As the horizon increases, the PERR in DSGEs increases because of the endogenous response of monetary policy and other variables (causing e.g. the PERR to the demand shock to quickly turn positive in the DSGE). The PERR is overall much lower in the BVARs than in DSGEs at horizons larger than 4 quarters from the shock. This may also be caused by the quick dynamics imposed in the sign restrictions of the BVARs, as most restrictions are imposed at impact. By contrast, the price rigidities embedded in the DSGEs slow down some responses: for instance, a reaction to monetary policy shocks needs more than one quarter to be transmitted.

The highest value in BVARs is experienced in case of monetary policy shocks (either domestic or relative); this is in line with the literature. This is especially true in Comunale and Kunovac (2017). The PERR for the exogenous exchange rate shock is particularly relevant for import prices, while smaller than the other shock-dependent PERRs for consumer prices.

For the pass-through to consumer prices, BVARs found also an important PERR following domestic demand, even if with an opposite sign. The ratios suggest that domestic demand shocks seem to be related to pass-through on consumer inflation with a sign not theoretically expected - an exchange rate appreciation following a demand shock may increase domestic prices. In other words, the increase in prices after demand shocks may offset a standard negative impact of exchange rate appreciation on prices. This may have important consequences for how we assess the pass-through when the euro exchange rate movement is predominantly driven by demand shocks. The puzzling sign of domestic demand shocks pass-through ratios is found also in the DSGEs medians but only for Q1. It is good noting that the PERRs to the demand shock is positive in the DSGE medians here reported for the remaining quarters, however there are differences across models, with some of them experiencing also negative values at later horizons (see Ortega and Osbat (eds.) (2020) and Pisani (2019)).

In order to better understand the role of domestic demand shocks on prices, we look more closely into the IRFs of these shocks on interest (shadow rates), as monetary policy instruments. We find a very significant negative and persistent response in the BVARs if the rate is taken in relative terms with respect to the US (as in Comunale and Kunovac (2017)). The same applies when we look at global supply shocks on interest rates. If we look at only euro area shadow rates, we have only a positive (borderline) significant reaction to these shocks at impact, and then they return rapidly to zero. This negative effect of domestic demand shocks on (relative) monetary policy can be a way to look at the unexpected sign in the ratios for consumer prices.

Summing up, for domestic demand, in the agnostic approach of BVARs the sign of the PERR is always negative for consumer prices, while in the fully structural DSGE the sign of the pass-through ratio mainly

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<sup>27</sup> See Table 1 for more details on the identifications.



reverts. We can see a negative sign in the case of import prices only in the model by Comunale and Kunovac (2017). Lastly, domestic supply shock-driven ratios in DSGEs are also negative, mostly in Q1 only.

Upon closer inspection of the models among the various available DSGEs (see Pisani, 2019 and Ortega and Osbat (eds.), (2020)), we see some outliers when looking at the monetary policy shock across all horizons. For monetary policy shock, the model by the Bank of Italy represents the median across all horizons in pass-throughs to consumer prices, while the NBB and Bundesbank models are the key values for import price medians. The magnitude in the ratios for UIP shocks and consumption preference are more comparable. For technology shocks, some outliers are found especially in one specific quarter (usually after 12Q) and they are different models for consumer prices and import prices (outliers are ECB-NAWM and Bundesbank and Bank of Romania for the latter).

As for the BVARs, looking at the same percentiles (16-84) across models, for consumer prices we find ratios different from zero in the case of an exogenous exchange rate shock in the short-run, and for the entire horizon for domestic supply, in Leiva et al. (2020). As for Comunale and Kunovac (2017) and Forbes et al. (2018), domestic demand-dependent PERR are always significantly different from zero, as are the ratios for exogenous exchange rate and relative monetary policy shocks. Looking at the PERR to import prices, again only the ratios for exogenous exchange rate and relative monetary policy shocks are significant.

### 7.3. Historical shock decomposition: robustness and uncertainty

The previous section established that in terms of shock-dependent price-to-exchange rate ratios (PERRs), the results are relatively robust qualitatively across DSGE and BVARs. The next question is: What is the constellation of shocks at any given time?

The historical shock decomposition is, in a way, the “narrative” that a given model provides about the economic forces driving the economy. It turns out that establishing robustness of such narratives is much harder than establishing the shape of impulse responses and their ratios. This sub-section shows the different historical decompositions coming from the BVARs and the DSGEs. The structural VARs offer alternative historical shock decompositions of the exchange rate evolution, depending on different definitions of variables, identification schemes, and specifications. The DSGEs can give guidance by giving more discipline on the responses and by looking at the background mechanisms and understanding the motivations of such responses (see Pisani, 2019). Comparing quarter-by-quarter decompositions across many models is not very fruitful, but an alternative way to see if the results are at least qualitatively robust is to report the cumulative historical decomposition for a specific episode of interest.

We report here the different BVARs decompositions for the nominal exchange rates (the decompositions of HICP and GDP are available in Appendix II and IV respectively); in Chart 1 we compare Comunale and Kunovac (2017) with Forbes et al. (2018) and Leiva et al. (2020). It is worth noting that these studies use two different exchange rates, broad NEER for the first two models and EURUSD for the latter.

[Insert Chart 1 here]

In all cases, EA demand shock, domestic (or relative) monetary policy, and exogenous exchange rate shocks play a role in explaining exchange rate fluctuations. The major contrast is in the role of domestic supply shock, which is the major driver only in Leiva et al. (2020), especially in 2015. As for the last observation for the bilateral rate vis-a-vis the USD, we see a prominent positive effect of exogenous exchange rate shocks, as



well as of relative monetary policy. This could be driven by both US policy actions and domestic ones, as indeed found in the decomposition in the Montes-Galdon et al. (2019) setup until 2017Q4.<sup>28</sup>

Then we show that the cumulative contribution of exchange rate and domestic shocks changes in the exchange rate from 2017 to the last available quarter in Chart 2. Next, we report the cumulative historical decomposition for the episode of the announcement of APP in Chart 3. Domestic shocks are taken as the sum of (various) shocks relative to demand factors, namely, monetary policy shocks and domestic and foreign demand shocks. Given the very different identifications and variables used in these BVAR models, which make the three demand shocks heterogeneous, this chart allows us to look at the general differences in contribution of demand compared with the exogenous exchange rate shocks. The last sub-chart refers to monetary policy shocks only, either in relative terms or for the EA and the US separately.

[Insert Chart 2 and 3 here]

For the last quarters up to 2018Q2 (with actual data until that point in time), the euro area monetary policy shock in the identification of Forbes et al. (2018) explains a major part of changes in the exchange rate. In this BVAR, foreign monetary policy shocks are not identified and the contribution of domestic monetary policy basically mirrors the one of foreign demand, which may include US monetary policy as well. Taking the net contribution of these two shocks from the Forbes et al. (2018) identification yields very similar results to those of the model by Comunale and Kunovac (2017).

Next, we use the period just before and following the announcement of APP, i.e. from 2014Q1 to 2016Q2, to look at whether the models agree qualitatively on the cumulative contribution of shocks to cumulative changes in exchange rates (with the updated data to 2019Q1-Q2). The exchange rates started appreciating after 2014Q3 (EUR versus USD) or 2014Q4 (nominal effective euro exchange rate). In DSGEs the UIP shocks can anticipate depreciation one quarter ahead, partially dampened by the appreciation due to demand shocks. In BVARs, a contribution of foreign exchange rate shocks is most pronounced, especially in the case of NEER. All BVAR models find that the overall demand shocks explain a substantial part of change in the exchange rate, while the monetary policy shocks play a minor role. In the CK model, global shocks also seem to matter.

Overall, in BVARs especially, all shocks contribute relatively little to observed changes in the exchange rate and in HICP over time. This points to the key contribution of systematic factors, which has not been captured by the historical shock decomposition. We find a similar outcome looking at the most recent quarters available. However, in the APP announcement period, we do see some contributions of exogenous exchange rates and demand shocks.

## 8. LOCAL PROJECTIONS: RESULTS FOR EURO AREA MEMBER STATES

The modelling challenges of analysing shock dependence of the impact of exchange rate changes increase further when looking at individual countries: for DSGEs because they imply a large modelling effort overall and for BVARs because exchange rate and monetary policy shocks cannot be identified using data from only one country. Even greater modelling challenges arise if we want to look at the shock-dependent impact of exchange rates broken down into subcomponents of HICP or trade prices.

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<sup>28</sup> We do not report the decomposition for Montes-Galdon et al. (2019) because the data points end in 2017Q4.

At the same time, we want to assess how HICP and its subcomponents, including HICPX, as well as import prices, react to the euro area shocks that can be identified via BVARs, i.e. the exchange rate or monetary policy. This exercise also allows us to look at the possible heterogeneous reactions across member states.

Hence, we make use of the shocks coming from all the BVARs, including them in the local projection regression (see equation 4) . We summarise the results by showing medians and confidence bands across models. Moreover, we provide the responses of prices by using the estimated shocks for the past in the NBB DSGE case.

### 8.1. Country-specific results with BVARs shocks

The impact of exchange rate shocks on HICP (Chart 4) is the largest in some new member states, such as the Baltic States and Malta,<sup>29</sup> but the range of estimates across models is wide. In general, using the relative monetary policy shocks (Chart 5), we can see heterogeneity across BVARs not only in the new member states, but also in some older members. This heterogeneity is very much in line with Lane and Stracca (2018). HICPs in France and Germany react basically in the same way as the overall euro area to relative monetary policy shocks. Disentangling the two different components, i.e. euro area and US monetary policies, we can see that generally euro area monetary policy plays a larger role for HICP, as expected.

[Insert Chart 4 and 5 here]

Looking at HICP, excluding food and energy, i.e. HICPX or core HICP,<sup>30</sup> the coefficients for an exogenous exchange rate shock and for relative monetary policy are normally lower than for HICP, and very close to zero for most of the old euro area countries in the case of exchange rate shocks. For the euro area monetary policy shock, the reaction of HICPX is very comparable to the one on HICP for all the considered countries. However, some larger reactions can be seen in some of the periphery countries: Greece, Ireland and Portugal.

The main difference between the results for HICP and HICPX in euro area countries is the reaction to a US monetary policy shock, which is lower for HICPX and basically zero for the old euro area countries, while comparable to the one for the euro area monetary policy in new member states.

Looking into HICP components in case of monetary policy shocks, it appears that the pass-through of exchange rate shocks to HICPX is small because of both sub components, i.e. the prices of services and of non-energy industrial goods (NEIG). For exogenous exchange rate shocks, the responses of prices of services seem to be smaller and driven by the outcomes of HICPX, especially in new member states.

### 8.2. Country-specific results with NBB DSGE shocks

We look now at how HICP (Chart 6) and HICPX (Chart 7) react to the estimated UIP (the EURUSD exchange rate shock) and monetary policy shocks for the past in DSGEs.<sup>31</sup> Here we do not have the median across models, as in the BVARs, but we show the confidence intervals based on NBB DSGE.

[Insert Chart 6 and 7 here]

Starting with UIP shocks, in both the HICP and the HICPX case, the magnitudes are not far from those of the BVARs, i.e. of around 0.10, but generally not significant at 95%. However, the heterogeneity across new

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<sup>29</sup> For more details on the ERPT and PERR in the Baltic States, see Comunale (2019).

<sup>30</sup> See the complete set of results in Appendix III: Chart A.4-A.9.

<sup>31</sup> Results for non-energy industrial goods price index and services price index are available upon request.

member states for the DSGE is more evident. In this case, countries like Lithuania and Slovakia show higher and significant shock-dependent pass-through to HICP compared with the aggregate euro area and their peers. As for the HICPX, we have the same situation for Malta and, once again, Slovakia, while Lithuania and Latvia even experiencing unexpected negative signs. This latter finding comes from the non-energy industrial goods.

As for euro area monetary policy shocks, the magnitudes are much larger when the shocks from the DSGE are applied. Nevertheless, once again we see the differences between old members, with coefficients close to zero, and the very dispersed results for new members. For monetary policy shocks, the pass-through HICPX is instead larger also for the euro area periphery, for instance for Greece, Ireland and Portugal, both for the BVARs and the NBB DSGE.

## 9. TIME VARIATION

### 9.1. Time varying PERR from BVARs

We present here a possible way to compute time varying PERRs (TV-PERRs) for the euro area and member states, as described in Comunale and Kunovac (2017). This TV-PERR measure is built as a linear combination of individual pass-through ratios over all shocks, weighted by the relative importance of that shock in the historical decomposition of FX (see Equation (5)):

$$PERR_t^j = \sum_{k=0}^K \theta_k (1) \widetilde{y}_{j,t}^k \quad (5)$$

$\theta_k(1)$  denoting the PERR ratios at 1-year horizon and  $\widetilde{y}_{j,t}^k$  is the relative contribution of the  $k$ th structural shock to the  $j$ th variable at period  $t$ . Time variation here is a natural consequence of a different composition of shocks hitting the euro area economy over time. The complete historical decomposition for the FX is available in Chart 1 and discussed in Section 7.3.

It is important to stress that this way to compute a TV-PERR depends heavily on the historical decomposition of FX, and we need therefore to look at how much our four common shocks are able to explain in terms of FX changes (see Section 7.3). Moreover, the TV-PERRs are now built by using all the PERR ratios, regardless of their significance. When exchange rate is mostly driven by monetary policy or exogenous exchange rate shocks, one could expect stronger TV-PERRs in the short and medium run (see Chart 8).

[Insert Chart 8 here]

In Comunale and Kunovac (2017), the results are also available for Italy, France, Germany, and Spain. The results for consumer prices are very close to zero as they are for the euro area as a whole, while for import prices the values look considerably different in the single countries, i.e. larger for Spain and Italy.

### 9.2. Time varying parameter dynamic factor model

A time-varying parameter dynamic factor model, as in Leiva et al. (2020), is reported here to identify potential changes in the response of euro area inflation to exogenous exchange rate shocks only.<sup>32,33</sup> The authors estimate a time-varying parameter factor model with exogenous information (TVP-DFX) on the HICP

<sup>32</sup> The results shown in this Section 9.2 come directly from a previous version of Leiva et al. (2020) with data up to 2018Q4.

<sup>33</sup> More details on the multivariate framework subject to time-varying coefficients are in Ductor and Leiva-Leon (2016).

inflation rates and components of all euro area countries for the period 1995Q1-2018Q4, and the shocks series which have explained the movements in the exchange rate, as identified in the previous BVARs. This method allows the capture of a common factor (the estimated factor can be interpreted as a proxy for the euro area inflation dynamics) and for a decomposition of the effect of exchange rate shocks on inflation in a country-specific and a regional component.

Here we report the inflation responses to changes in the exchange rate due to purely exogenous shocks, unrelated to fundamentals. The estimates indicate that the sensitivity of euro area headline inflation to exogenous exchange rate shocks has remained relatively steady over time. Nevertheless, there has been a slightly increasing sensitivity of HICP inflation after the period associated with the Great Recession. These results are obtained when using the shocks estimated from the structural BVAR proposed in Leiva et al. (2020). Similar results are found when alternatively using exogenous exchange rate shocks extracted from BVAR models which involve different sets of information and identification schemes (here the schemes are from Comunale and Kunovac (2017) and Forbes et al. (2018)). Chart 9 reports these comparisons, which also show some differences in the level of sensitivity across specifications.

[Insert Chart 9 here]

The sensitivity of the energy and food component of inflation to exogenous exchange rate shocks has significantly increased since the Great Recession. The TVP-DFX framework is applied to different subcomponents of headline inflation. For the case of the energy component, its sensitivity to exogenous exchange rate shocks has increased in recent years. For the food component, the pattern is similar to the case of headline inflation, although with less significance and some heterogeneity across specifications during recent years. Core inflation, by contrast, does not seem to be meaningfully affected by exogenous exchange rate shocks. Similar results are found in Leiva et al. (2018) when applying a like analysis to the case of the Spanish economy.

When applying the factor model to assess cross-country heterogeneity, the estimates indicate a generalized and persistent increase in the effect of shocks on inflation which occurred around 2010 across euro area members. This is especially so in Spain and also Italy, France, and Germany. Other member states, such as Portugal, Finland or Malta, have also experienced an increasing sensitivity, but of a smaller magnitude. Since for the overall euro area, in contrast, the effect has remained steady, this implies an increase over time in the synchronization of HICP dynamics for most of the countries. This TVP-DFX setup has been applied in Leiva et al. (2020) to components of HICP (core, food and energy prices). As for core HICP, the effect is both negligible and very uncertain across countries. Moreover, there is a substantial level of heterogeneity in the co-movement of core inflation, with Baltic States even showing a decreasing co-movement over time. While the increase in the effect of exchange rate shocks on inflation, occurring since 2010, has been significant in the case of energy, it has been rather weak and more uncertain in the case of food.

## 10. CONCLUSIONS

Overall, we conclude that different domestic and global shocks are associated with widely different pass-throughs, and that country characteristics may matter. On impact, the Price-to-Exchange Rate Ratios are similar across DSGEs and BVARs. At longer horizons, the PERRs in DSGEs increase because of the endogenous response of monetary policy and other variables. The highest value in BVARs is experienced in the case of

monetary policy shocks (either domestic or relative); this is in line with the literature. In general, there is little to no consensus for GDP across models. Overall, in BVARs especially, there is a small contribution of shocks to both changes in exchange rate and in HICP over time, which indicates the key contribution of systematic factors. We do find a contribution for domestic demand and exogenous exchange rate shocks in the APP announcement period.

Looking at country-specific results, the impact of exchange rates on HICP is the largest in some new member states, such as the Baltic States and Malta. HICPs in France and Germany react similarly to the overall EA to relative monetary policy shocks, and the impact is rather small. Generally speaking, euro area monetary policy plays a bigger role for consumer prices, especially for new member states and the euro area periphery. This heterogeneity within the euro area accords well with Lane and Stracca (2018). Accounting for time-variation, exogenous shocks to exchange rate seem to have passed to HICP with more intensity after 2010, and this is particularly true for most of the old euro area countries.

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## ANNEX: TABLES AND FIGURES

**Table 1: Identification in BVARs: Short-run restrictions for the 4 common shocks**

**CK: Comunale and Kunovac (2017)**

	<b>GDP</b>	<b>HICP</b>	<b>ReI IR</b>	<b>FX (NEER)</b>	<b>IP</b>
<b>EA demand shock (AD)</b>	1	1	1	app	*
<b>EA monetary policy (MP) <b>RELATIVE to US</b></b>	1	1	-1	dep	*
<b>Exogenous exchange rate shock (FX)</b>	*	1	*	dep	1
<b>EA supply shock (AS)</b>	-1	1	*	*	*

**BdE: Leiva et al. (2020)**

	<b>GDP</b>	<b>HICP</b>	<b>ReI IR</b>	<b>FX (EURUSD)</b>	<b>ReI GDP</b>
<b>EA demand Shock (AD)</b>	1	1	1	*	1
<b>EA monetary policy (MP) <b>RELATIVE to US</b></b>	-1	-1	1	*	-1
<b>Exogenous exchange rate shock (FX)</b>	1	-1	-1	app	*
<b>EA supply shock (AS)</b>	1	-1	-1	dep	1

**PAC: Montes-Galdon et al. (2019)**

	<b>GDP</b>	<b>HICP</b>	<b>IR</b>	<b>FX (EURUSD)</b>
<b>EA demand shock (AD)</b>	1	1	*	app
<b>EA monetary policy (MP)</b>	*	1	-1	dep
<b>Exogenous exchange rate shock (FX)</b>	*	1	1	dep
<b>EA supply shock (AS)</b>	-1	1	0	*

**Forbes: Forbes et al. (2018)**

	<b>GDP</b>	<b>HICP</b>	<b>IR</b>	<b>FX (NEER)</b>	<b>IP</b>
<b>EA demand shock (AD)</b>	1	1	1	dep	*
<b>EA monetary policy (MP)</b>	-1	-1	1	dep	*
<b>Exogenous exchange rate shock (FX)</b>	*	-1	-1	dep	1
<b>EA supply shock (AS)</b>	1	-1	*	*	*

**BdI: Conti et al. (2017)<sup>34</sup>**

	<b>GDP</b>	<b>HICP</b>	<b>IR</b>	<b>FX (NEER or EURUSD)</b>	<b>Rel GDP</b>
<b>EA demand shock (AD)</b>	1	1	1	app	1
<b>EA monetary policy (MP)</b>	1	1	-1	dep	1
<b>Exogenous exchange rate shock (FX)</b>	1	1	*	dep	0
<b>EA supply shock (AS)</b>	-1	1	*	*	-1

Note: App denotes appreciation and dep denotes depreciation. IR is interest rate, Rel IR is relative interest rates EA-US, FX is the exchange rate either NEER or EURUSD, HICP are consumer prices and IP are import prices. EA stands for euro area. Rel GDP in BdE and BdI is Real GDP EA-US. "1" denotes positive sign, "-1" denotes negative, "0" denotes zero restriction and "\*" denotes unrestricted response. PAC also includes US monetary policy as an endogenous variable, while BdI treats it as exogenous.

<sup>34</sup> This approach also uses real oil prices and CISS. Conti et al. (2017) consider both EUR/US and broad NEER. We reverse the sign to make the ID comparable with its peers.

**Table 2: Identification in NBB DSGE: Short-run restrictions for the 4 common shocks**

DSGE					
	GDP	HICP	IR	FX (EURUSD)	IP
<b>EA demand shock (AD)</b>	1	1	1	app	*
<b>EA monetary policy (MP)</b>	1	1	-1	dep	*
<b>Exogenous exchange rate shock (FX)</b>	1	1	1	dep	1
<b>EA supply shock (AS)</b>	1	-1**	-1	dep	*

Note: \*\*negative only after a few quarters. App denotes appreciation and dep denotes depreciation. IR is interest rate, FX is the exchange rate, HICP are consumer prices and IP are import prices. EA stands for euro area. As for BVARs, "1" denotes positive sign, "-1" denotes negative.

**Table 3: Empirical estimates for shock-dependent ERPT/PERR to consumer prices in the euro area**  
(Impact after Q1-Q12 of 1% depreciation in exchange rate (NEER or EURUSD))

Shocks	Horizons	Median DSGEs	Median BVARs	Forbes	CK	BdE	BdI	PAC*
Exogenous exchange rate	Q1	0.00	0.07	0.06	0.09	0.07	0.05	
	Q4	0.10	0.07	0.04	0.08	0.06	0.16	
	Q8	0.30	0.07	0.03	0.08	0.05	0.21	
	Q12	0.50	0.07	0.03	0.08	0.05	0.23	
Domestic demand	Q1	-0.10	-0.08	-0.08	-0.07	-0.04	-0.16	
	Q4	0.20	-0.11	-0.11	-0.11	-0.07	-0.22	
	Q8	0.40	-0.12	-0.12	-0.12	-0.07	-0.30	
	Q12	0.60	-0.12	-0.12	-0.12	-0.07	-0.40	
Monetary policy	Q1	0.10	0.07	0.08	0.15	0.02	0.06	
	Q4	0.30	0.09	0.10	0.13	0.01	0.08	
	Q8	0.60	0.10	0.10	0.13	0.01	0.10	
	Q12	0.80	0.12	0.10	0.13	0.00	0.13	
Domestic supply	Q1	-0.20	-0.05	-0.05	-0.02	-0.09	-0.05	
	Q4	-0.30	-0.05	-0.07	-0.03	-0.08	-0.03	
	Q8	-0.20	-0.04	-0.06	-0.02	-0.08	0.04	
	Q12	-0.10	-0.04	-0.06	-0.02	-0.07	0.20	

Note: Impact after Q1-Q12 of 1% depreciation in exchange rate (NEER or EURUSD). Forbes refers to Forbes et al. (2018) identification, CK is Comunale and Kunovac (2017), BdE is Leiva et al. (2020), BdI is Conti et al. (2017). Forbes, BdI and CK use NEER-38, BdE instead includes EURUSD. Monetary policy is taken in relative terms with respect to the US in CK and BdE. Data points until 2019Q1 (or Q2). Median of the DSGEs is obtained from the euro area models as in Ortega and Osbat (eds.) (2020). The model by the Bank of Finland is not included in the results for the supply shock. PAC\* has data until 2017Q4 and is not considered for the median.

**Table 4: Empirical estimates for shock-dependent ERPT/PERR to import prices in the euro area**

(Impact after Q1-Q12 of 1% depreciation in exchange rate (NEER or EURUSD))

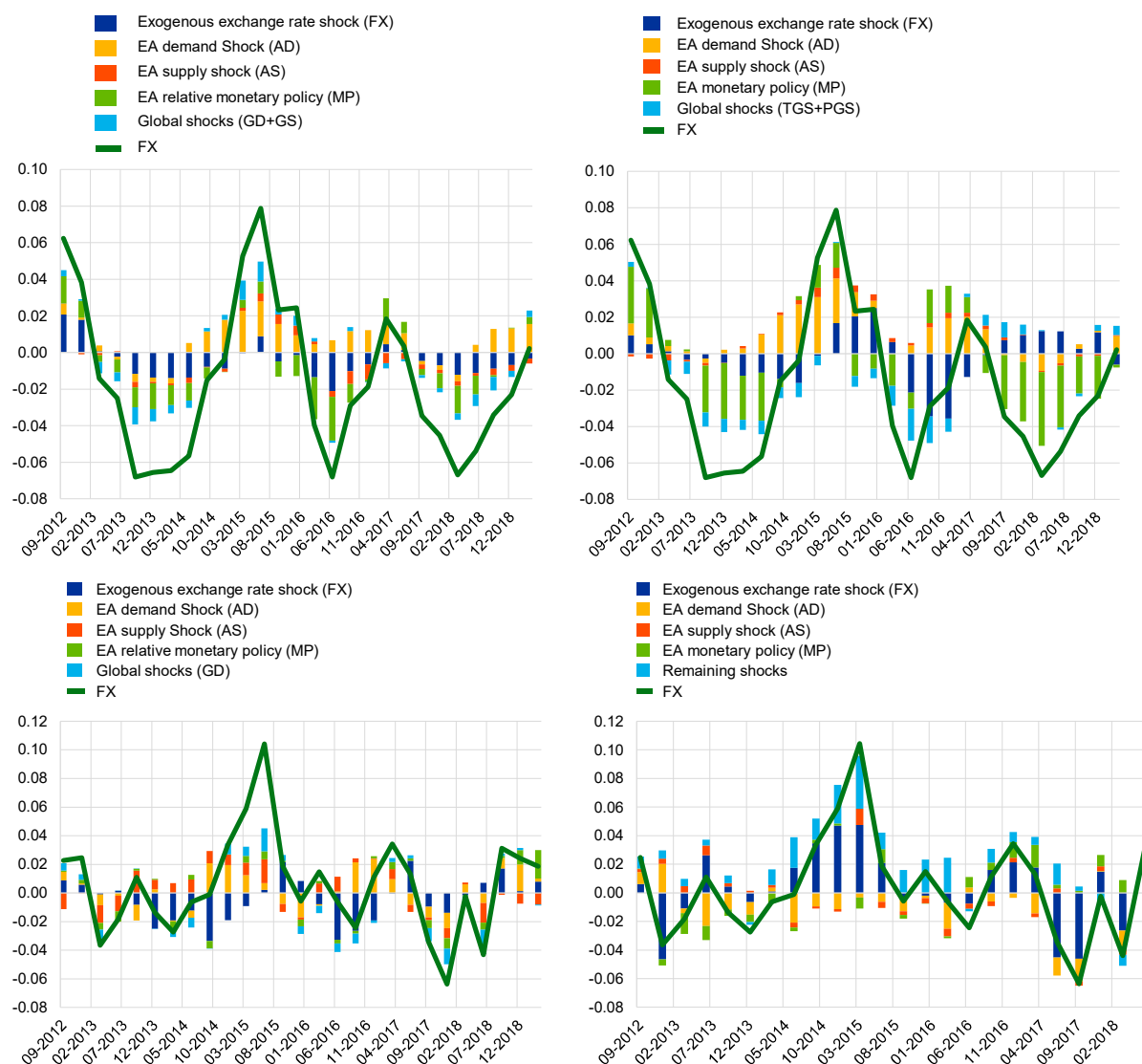
Shocks	Horizons	Median DSGEs (extra-EA import prices)	Median BVARs (total import prices)	Forbes	CK
Exogenous exchange rate	Q1	0.40	0.30	0.16	0.44
	Q4	0.80	0.35	0.21	0.49
	Q8	0.80	0.35	0.22	0.48
	Q12	0.80	0.35	0.22	0.47
Domestic demand	Q1	0.30	0.10	0.22	-0.03
	Q4	0.60	0.11	0.25	-0.03
	Q8	0.60	0.12	0.26	-0.02
	Q12	0.60	0.13	0.26	0.01
Monetary policy	Q1	0.40	0.45	0.25	0.65
	Q4	0.80	0.48	0.25	0.70
	Q8	1.0	0.46	0.24	0.69
	Q12	1.0	0.46	0.24	0.68
Domestic supply	Q1	0.30	0.17	0.17	0.16
	Q4	0.60	0.24	0.25	0.23
	Q8	0.60	0.25	0.26	0.23
	Q12	0.70	0.25	0.26	0.23

Note: Impact after Q1-Q12 of 1% depreciation in exchange rate (NEER or EURUSD). Forbes refers to Forbes et al. (2018) identification, CK is Comunale and Kunovac (2017), BdE is Leiva et al. (2020) and BdI is Conti et al. (2017). Forbes, BdI and CK use NEER-38, BdE instead includes EURUSD. Monetary policy is taken in relative terms with respect to the US in CK and BdE. Data points until 2019 Q1 (or Q2). Other BVARs not reported because they do not have import prices in their models. Median of the DSGEs is obtained from the euro area models as in Ortega and Osbat (eds.) (2020). Import prices are total prices for BVARs and extra-EA prices in the DSGEs (the DSGE medians reported in this table exclude the model by the Bank of Finland, which applies total import prices).



## Chart 1: Exchange rate shocks decomposition BVARs and NBB DSGE

((Data from 2012Q3 to 2019Q1 – NEER-38 for 1) CK (LHS) and Forbes (RHS) then EURUSD for BdE (LHS below) and DSGE (RHS below))<sup>35</sup>

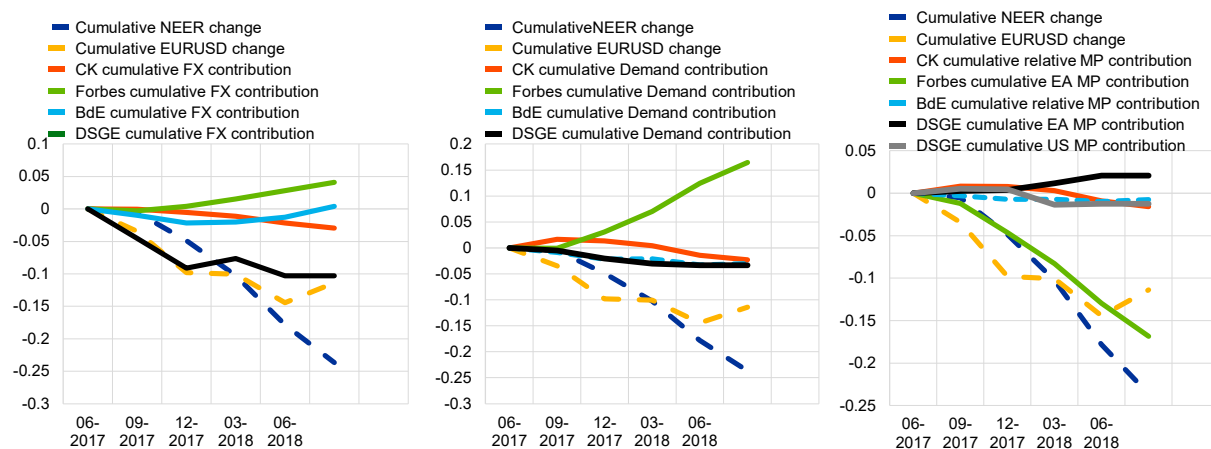


Note: Forbes refers to Forbes et al. (2018) identification, CK is Comunale and Kunovac (2017), BdE is Leiva et al. (2020), BdI is Conti et al. (2017) and PAC is Montes-Galdon et al. (2019). Forbes, BdI and CK use NEER-38, BdE and PAC instead includes EURUSD. Monetary policy is taken in relative terms with respect to the US in CK and BdE. DSGE are until 2018Q2.

<sup>35</sup> Decompositions for BdI with NEER or EUR/USD and PAC (until 2017Q4) are available upon request.

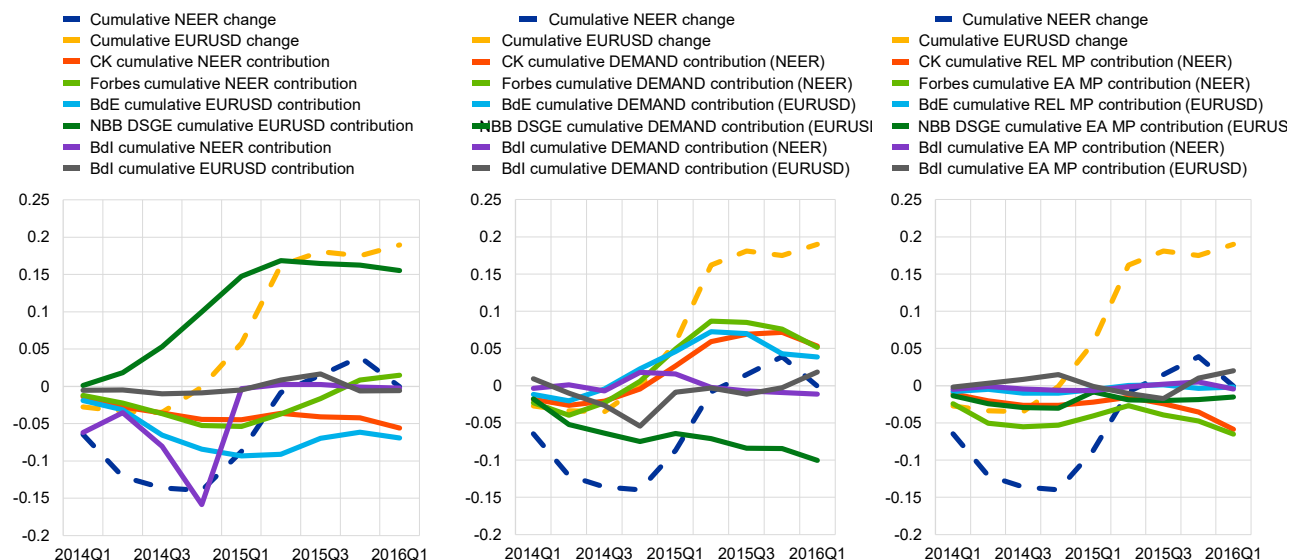
**Chart 2: Cumulative contribution of exchange rate and domestic shocks to change in FX from 2017Q1 to 2018Q2 – BVARs and NBB DSGE**

(Cumulated historical decomposition from 2017Q1 to 2018Q2 - LHS: exchange rate shock, in the middle: demand shock and RHS: monetary policy shocks)



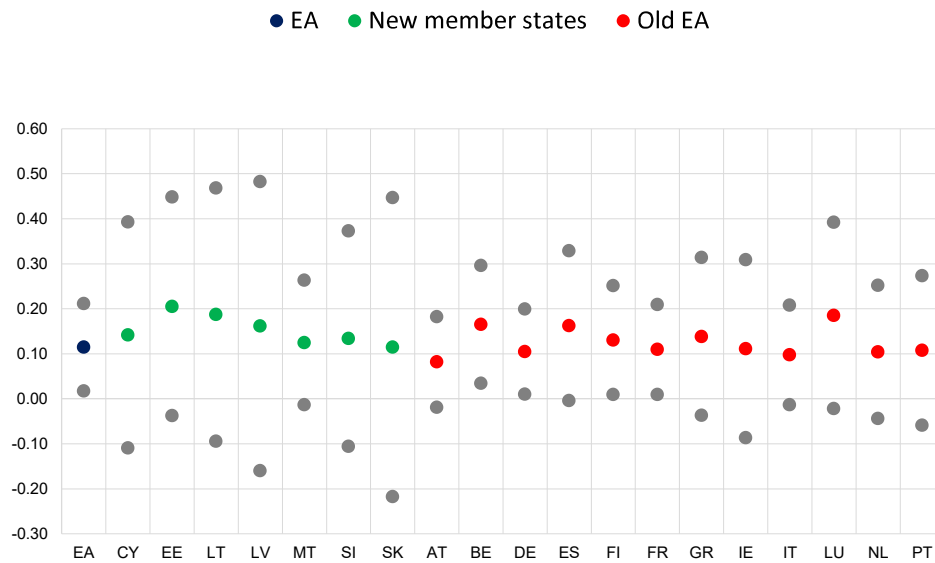
**Chart 3: Robustness of historical decomposition: the episode of the announcement of APP– BVARs and NBB DSGE**

(Cumulated historical decomposition from 2014Q1 to 2016Q1– LHS: exchange rate shock, in the middle: demand shock and RHS: monetary policy shocks)



#### Chart 4: The response to exchange rate shocks (HICP)

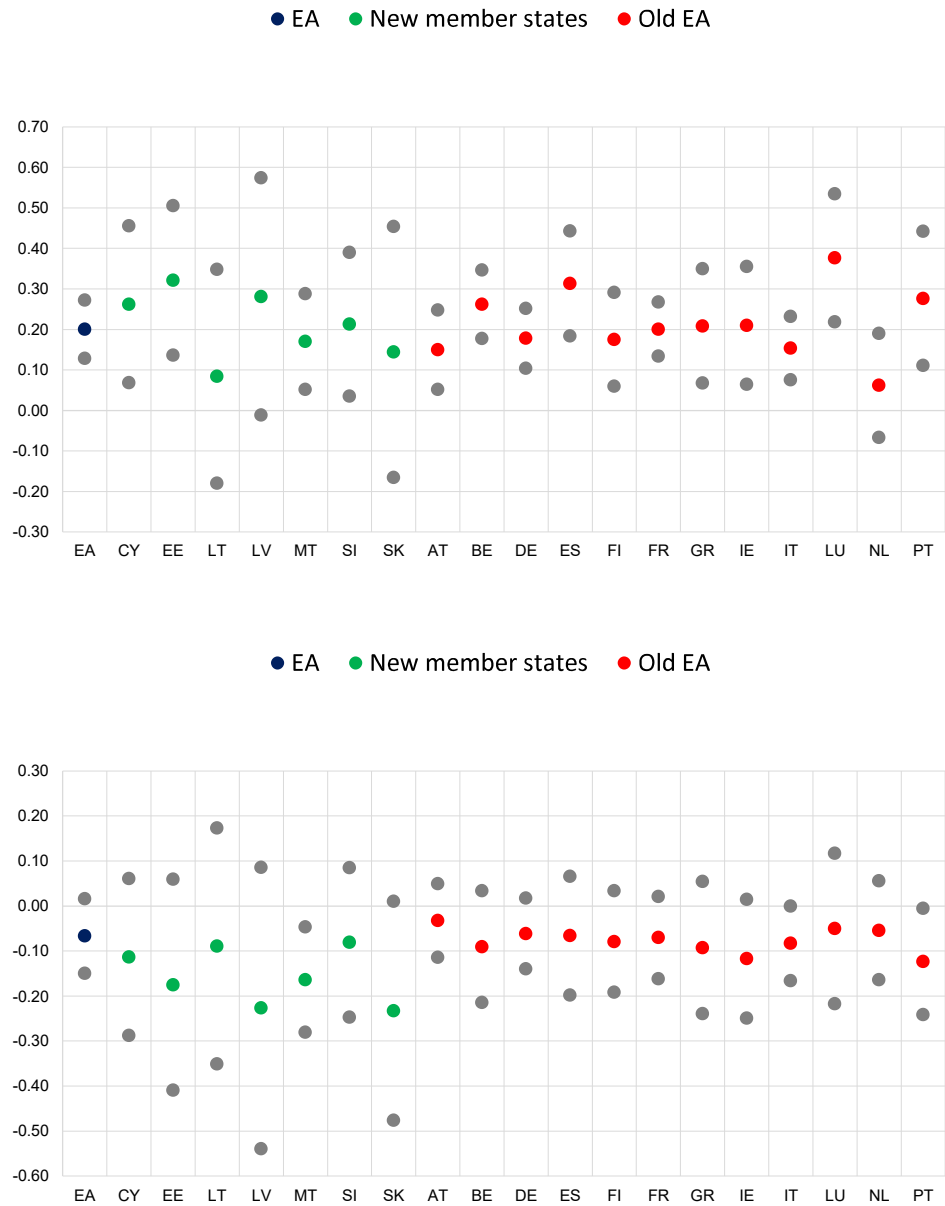
(Local projections. Median values with 95% bands. Results across BVAR models. Q1)

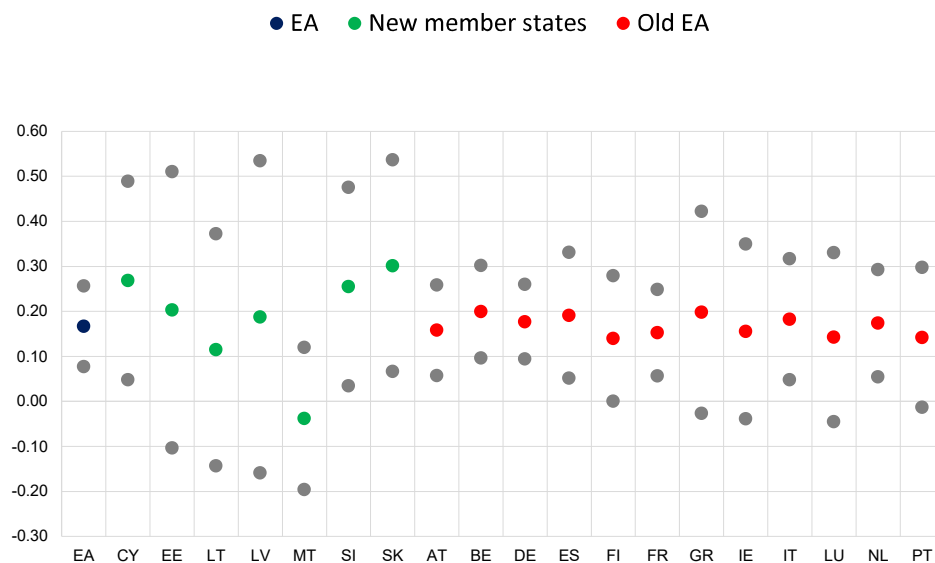


Note: Forbes refers to Forbes et al. (2018) identification, CK is Comunale and Kunovac (2017), BdE is Leiva-Leon et al. (2018), BdI is Conti et al. (2017) and PAC is Montes-Galdon et al. (2019). BVARs considered are CK, Forbes, BdE and BdI. Forbes, BdI and CK use NEER-38, BdE instead includes EURUSD. Data are until 2019Q1.

**Chart 5: (Relative) monetary policy shock (HICP)**

(Local projections. Median values with 95% bands. Results across BVAR models. Chart (a) is on relative MP, chart (b) about EA MP and chart (c) on US MP. Q1)

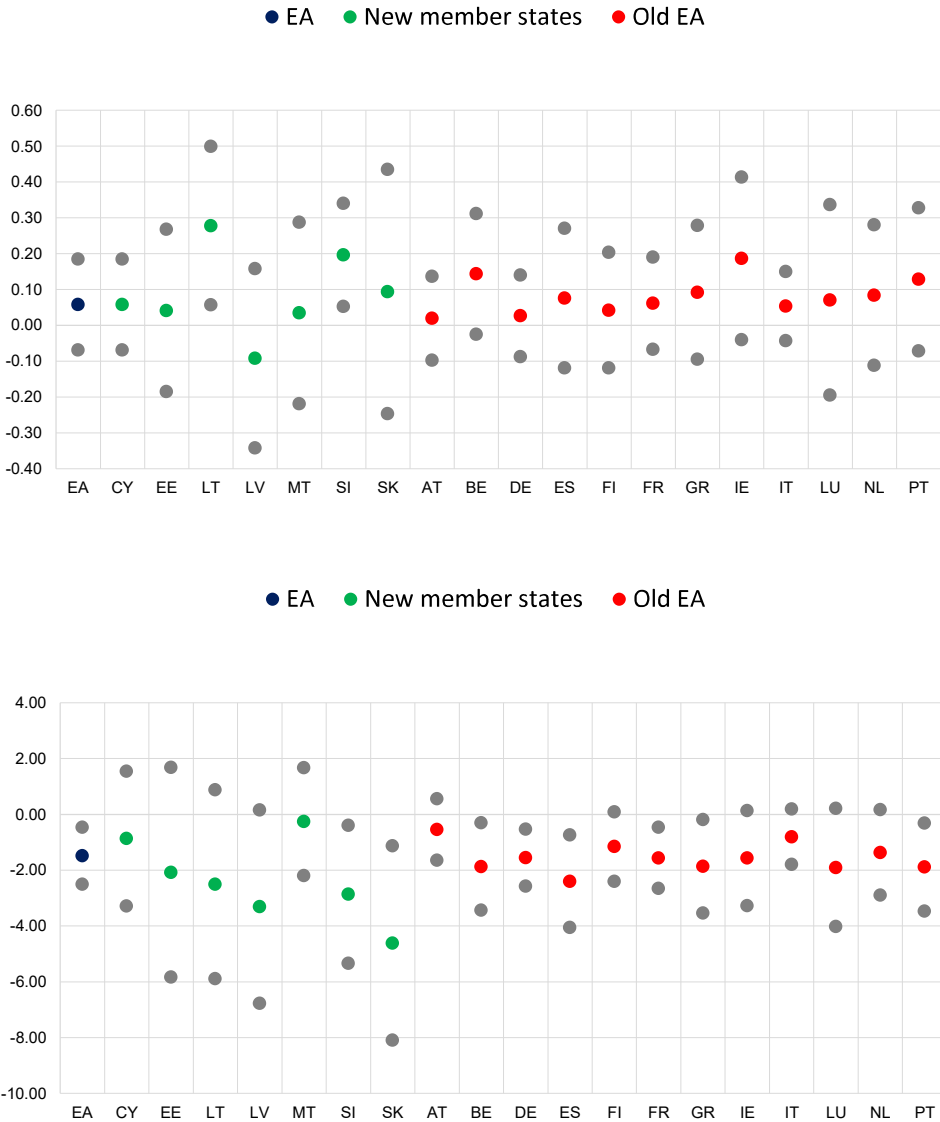




Note: Forbes refers to Forbes et al. (2018) identification, CK is Comunale and Kunovac (2017), BdE is Leiva-Leon et al. (2018), BdI is Conti et al. (2017) and PAC is Montes-Galdon et al. (2019). BVARs considered are CK, Forbes, BdE and BdI. Forbes, BdI and CK use NEER-38, BdE instead includes EURUSD. Data are until 2019Q1, except for US MP which comes from PAC and with data until 2017Q4.

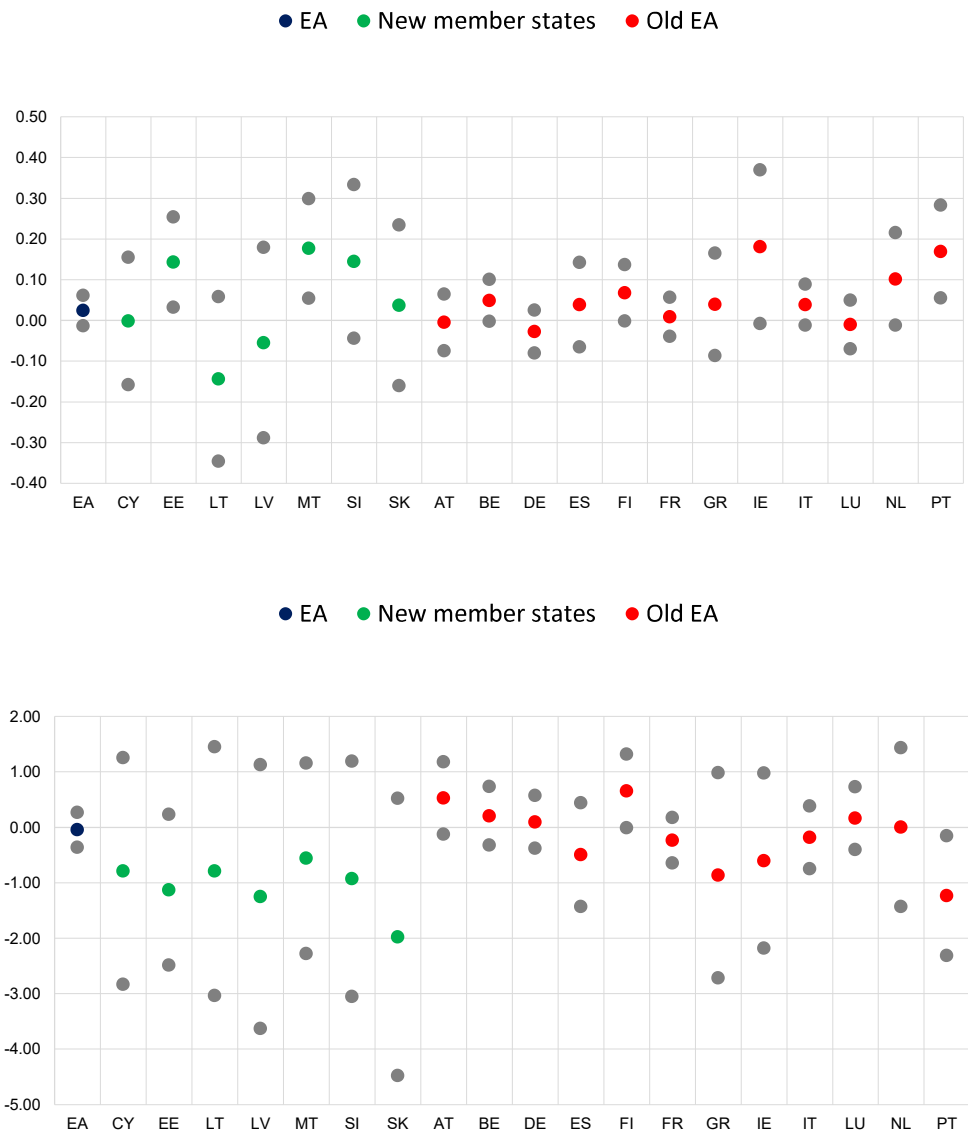
**Chart 6: The responses of HICP to UIP and monetary policy shocks - NBB DSGE**

(Local projections. Results by using shocks from NBB DSGE (a) is about UIP shocks, chart (b) about EA MP. Q1)



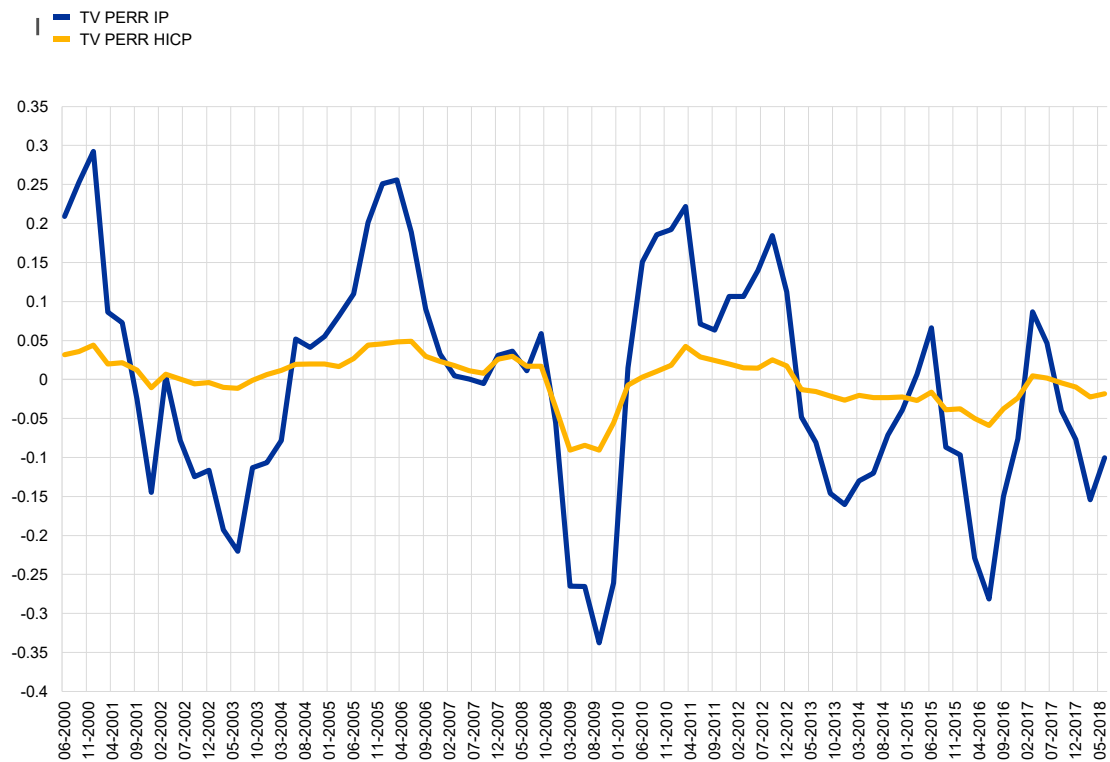
**Chart 7: The responses of core HICP to UIP and monetary policy shocks - NBB DSGE**

(Local projections. Results by using shocks from NBB DSGE (a) is about UIP shocks, chart (b) about EA MP. Q1)





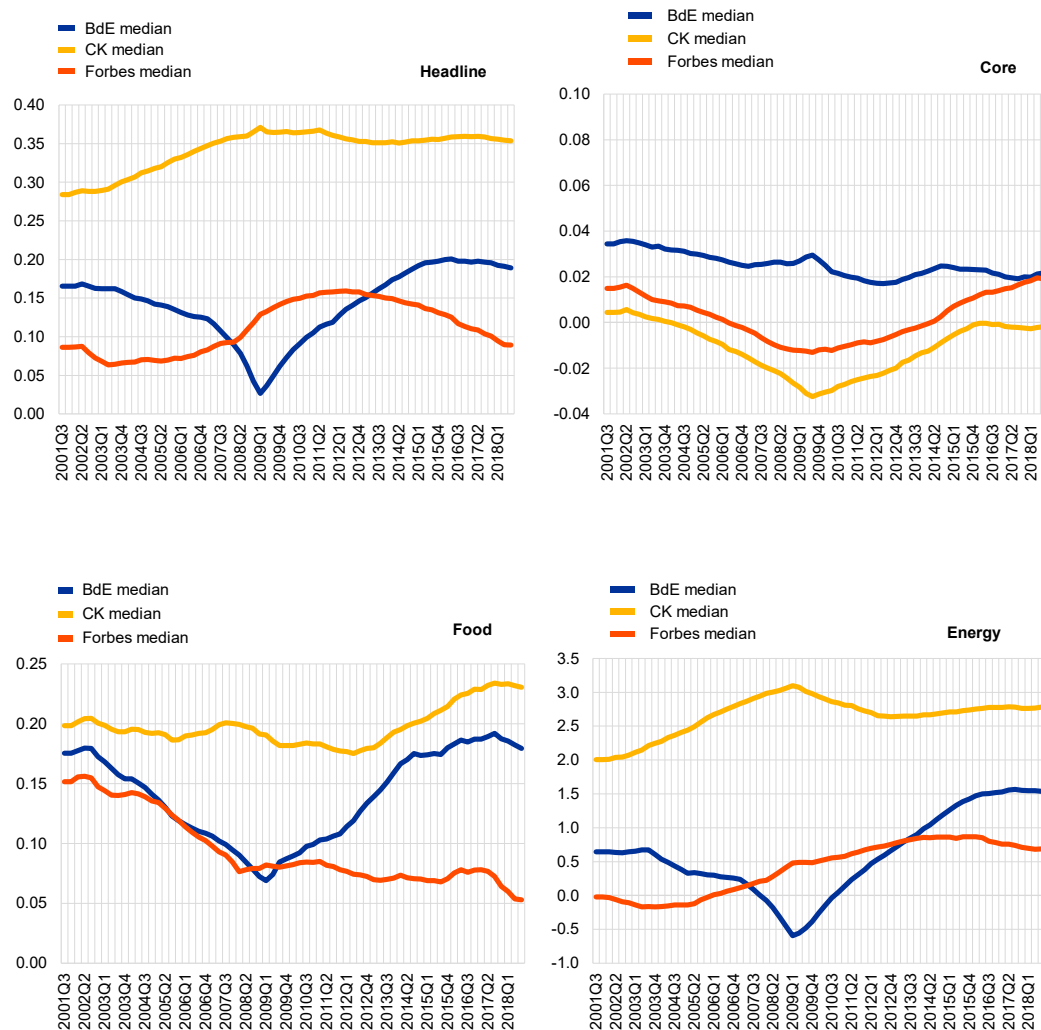
**Chart 8: Time-varying PERR from CK BVAR**



Note: Author's calculations based on Comunale and Kunovac (2017). Only the 4 common shocks are considered. The NEER historical decomposition is as in Comunale and Kunovac (2017) and reported in Chart 1. Data up to 2018Q2.

## Chart 9: Time-varying effect of exogenous exchange rate shocks to the components of euro area inflation

(From the top LHS: Headline, Core, Food and Energy)



Note: The source is Leiva et al. (2020). Forbes refers to the exercise using the shocks obtained by relying on the identification in Forbes et al. (2018), CK is Comunale and Kunovac (2017), BdE is Leiva et al. (2020).

## APPENDICES

### Appendix I: PERR in euro area member states: simple regressions including all common shocks

We regress, country by country, the prices on the euro area-common FX and monetary policy shocks from the BVARs in single regressions. More specifically, we have different inflation measures (yoy) as dependent variable  $Y_t$  and the outcomes from common FX and monetary policy shocks  $\epsilon_{t-j}$ . The shocks are used together in the regressions because they are orthogonal.<sup>36</sup> The common monetary policy shocks can be of 3 different types. We can have only an euro area monetary policy shock (following Forbes et al. (2018)), both euro area and US monetary policy shock as in the PAC approach, or a relative monetary policy shock á la Comunale and Kunovac (2017) or as in Leiva et al. (2020). The shocks are qoq variations.

$$Y_t = \alpha + \sum_{k=1}^3 \sum_{j=0}^4 \phi_{j,k} \epsilon_{t-j,k} + \varepsilon_t$$

In the formula above,  $k$  refers to the shocks and  $j$  stands for the lags from 0 to 4. So, we include here also the effect on impact. We run this regression for all the 19 euro area member states.<sup>37</sup> The  $\phi_{j,k}$  coefficients will be therefore country-specific.

We report below a scatter plot for the coefficients based on 3 different BVAR models, namely: Comunale and Kunovac (2017), Forbes et al. (2018) and Leiva et al. (2020). The selected horizon for the coefficients is after 4 quarters. This is in most cases significant.<sup>38</sup> We look here at HICP and core HICP.

We start looking at the two models with a relative monetary policy shock, i.e. Comunale and Kunovac (2017) and Leiva et al (2018). In general, using the relative monetary policy shock coming from these two differently identified BVARs, we can see a level of heterogeneity across member states; especially in the Baltic States (see Chart A.1). The two models are somewhat similar for the original members, with a larger difference for Ireland, Greece, France and the Netherlands. Latvia and Lithuania emerge as outliers. This is also reflected in Chart A.2, where we look at exogenous exchange rate shocks. The largest effect of these shocks on HICP is found in Estonia, Latvia, Finland and the Netherlands. German, France and Belgium experienced lower coefficients, less than -0.1.

As for core HICP, the coefficients for an exogenous exchange rate shock are normally lower than for HICP, very close to zero for Germany, France, Belgium and Malta in the Comunale and Kunovac (2017) and Forbes et al. (2018) specifications, which rely on NEER. This is not always confirmed when EURUSD is applied. In the case of monetary policy shocks, the distance between HICP and core HICP coefficients is very small when the monetary policy is considered in relative terms. When we take only an EA monetary policy shock, the coefficients tend to be much smaller in case of core HICP compared to HICP. Germany, France and Malta experience values very close to zero, while we see a substantial reduction in Spain, Italy, Greece and Cyprus.

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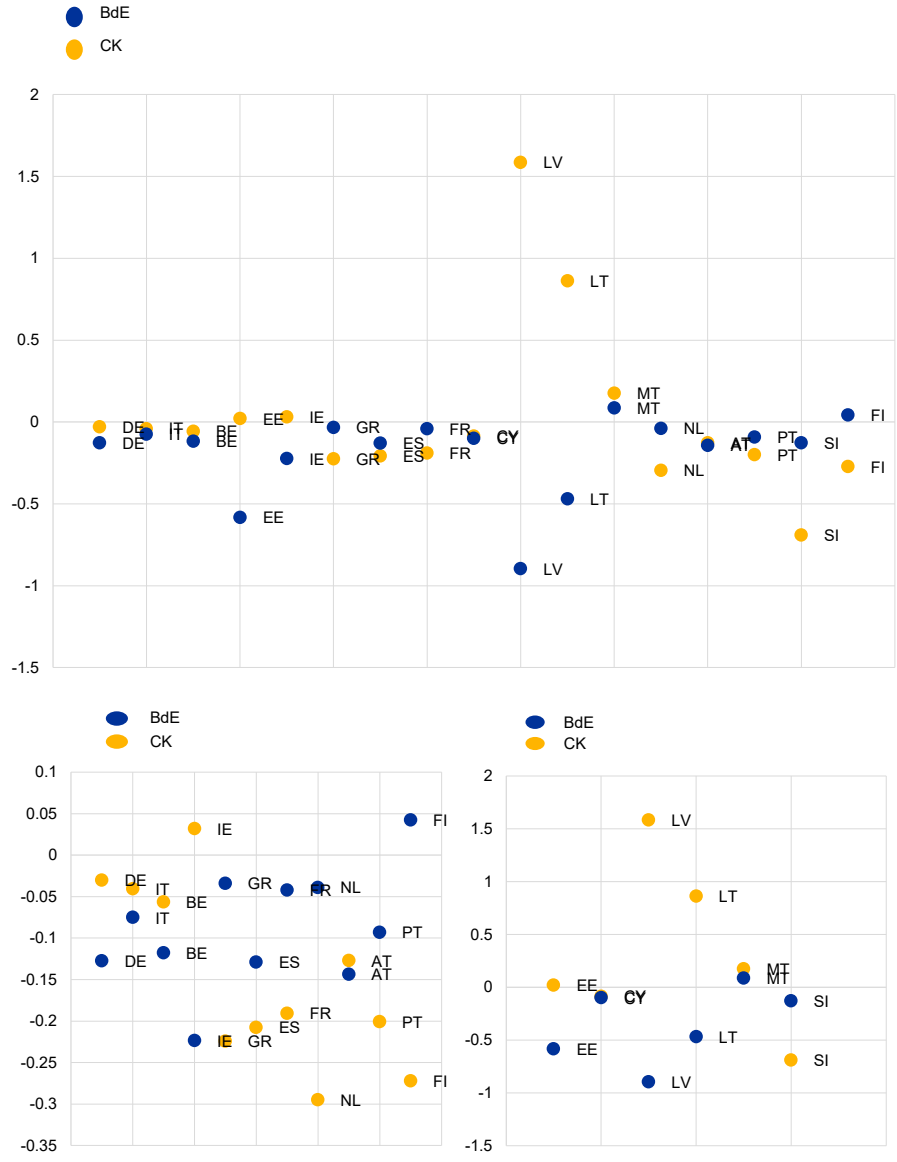
<sup>36</sup> The results with shocks taken separately available upon request; the differences in the coefficients are minor.

<sup>37</sup> Slovakia is not included, given limited data availability.

<sup>38</sup> The complete set of coefficients for all quarters from 1 to 4 is available upon request.

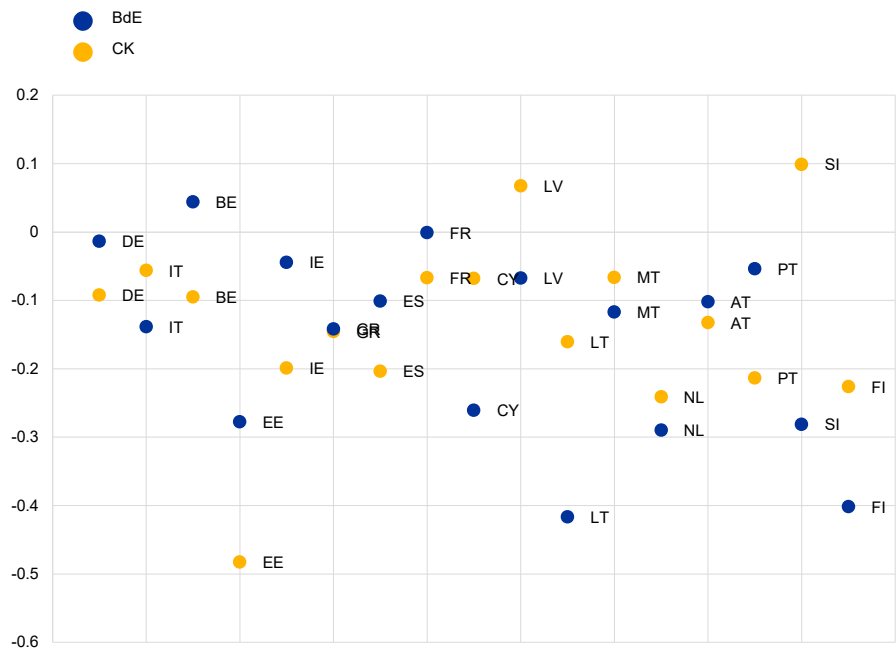
**Chart A.1: Comunale and Kunovac (2017) vs. Leiva et al. (2020) – relative monetary policy shock (HICP)**

(Coefficients after 4Q – EA-US monetary policy; BdE refers to Leiva et al. (2020). CK refers to Comunale and Kunovac (2017))



**Chart A.2: Comunale and Kunovac (2017) vs. Leiva et al. (2020) – exchange rate shock (HICP)**

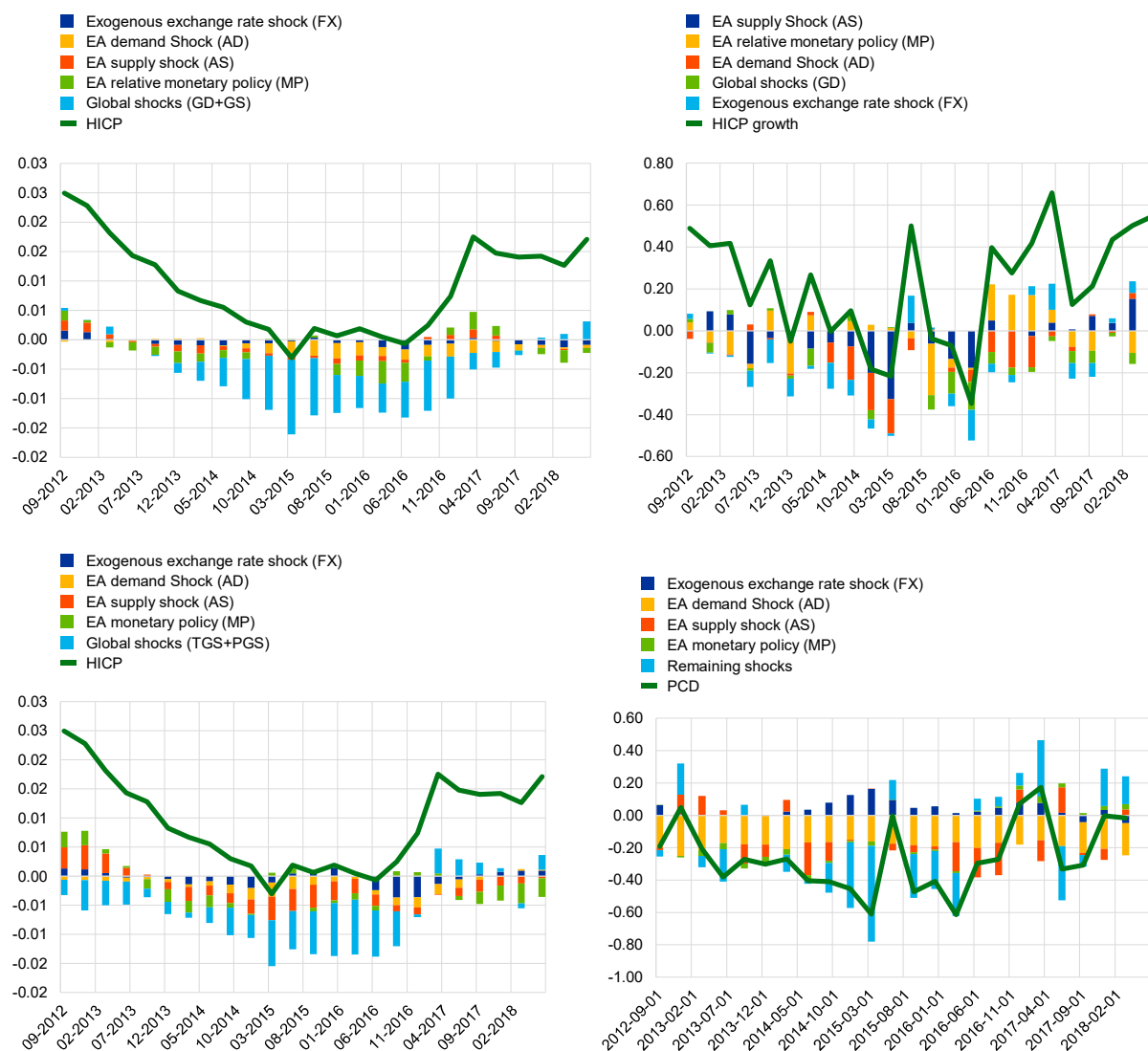
(Coefficients after 4Q – NEER-38 for CK and EURUSD for BdE. BdE refers to Leiva et al. (2020) and CK refers to Comunale and Kunovac (2017))



## Appendix II: Shocks decomposition of consumer prices

**Chart A.3: Consumer price shocks decomposition BVARs (CK vs. BdE vs. Forbes) and NBB DSGE**

(Data from 2012Q3 to 2018Q2 or Q3 – NEER-38 for CK (LHS) and Forbes (below LHS), EURUSD for BdE (RHS) and DSGE (below RHS) uses the consumer price deflators)

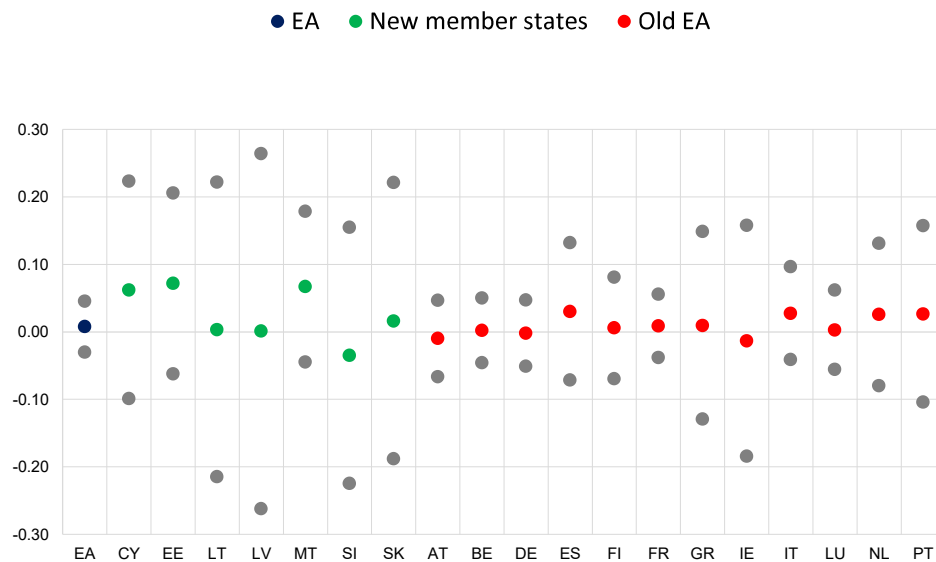


Note: Forbes refers to Forbes et al. (2018) identification, CK is Comunale and Kunovac (2017), BdE is Leiva et al. (2020). In the case of DSGE, the PCD is the consumer price deflator and not HICP, and taken in deviation from the mean:  $dPCD = 100 * \ln(PCD_t / PCD_{t-1}) - 0.4582$ .

### Appendix III: Core HICP and HICP components – cross-country responses to common shocks

#### Chart A.4: The response to exchange rate shocks (HICPX)

(Local projections. Median values with 95% bands. Results across BVAR models. Q1)

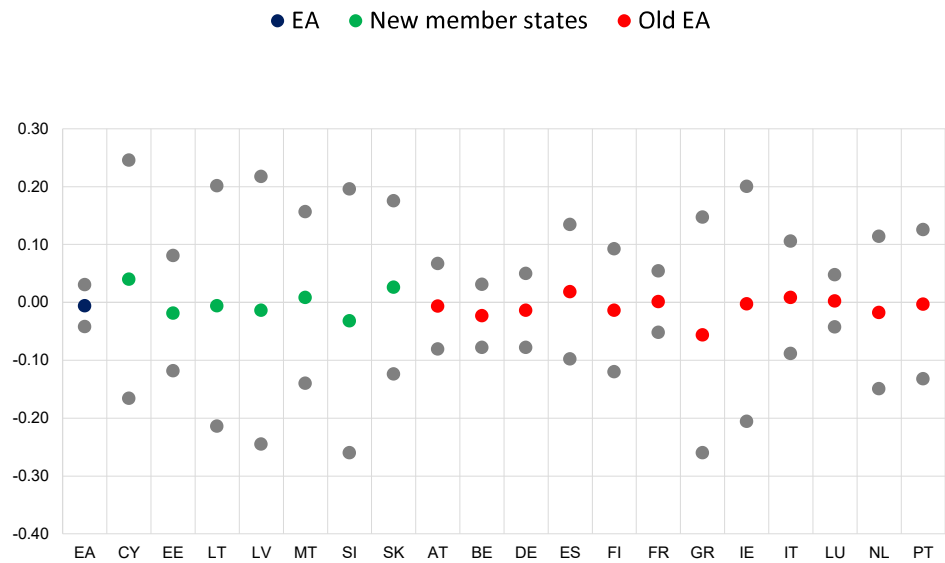


Note: Forbes refers to Forbes et al. (2018) identification, CK is Comunale and Kunovac (2017), BdE is Leiva-Leon et al. (2018), BdI is Conti et al. (2017) and PAC is Montes-Galdon et al. (2019). BVARs considered are CK, Forbes, BdE and BdI. Forbes, BdI and CK use NEER-38, BdE instead includes EURUSD. Data are until 2019Q1, except for US MP which comes from PAC and with data until 2017Q4.



**Chart A.5: The response to exchange rate shocks (NEIG)**

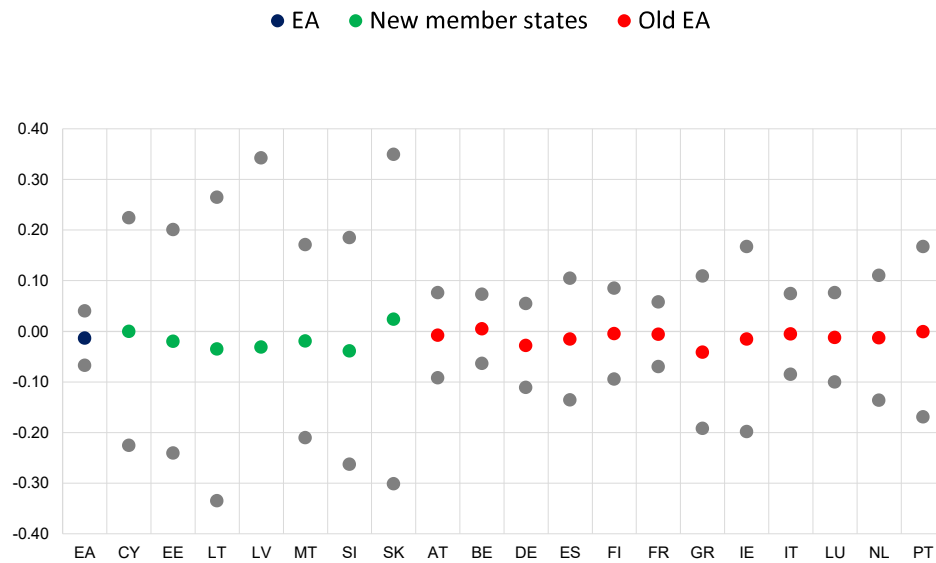
(Local projections. Median values with 95% bands. Results across BVAR models. Q1)



Note: Forbes refers to Forbes et al. (2018) identification, CK is Comunale and Kunovac (2017), BdE is Leiva-Leon et al. (2018), BdI is Conti et al. (2017) and PAC is Montes-Galdon et al. (2019). BVARs considered are CK, Forbes, BdE and BdI. Forbes, BdI and CK use NEER-38, BdE instead includes EURUSD. Data are until 2019Q1, except for US MP which comes from PAC and with data until 2017Q4.

### Chart A.6: The response to exchange rate shocks (SERV)

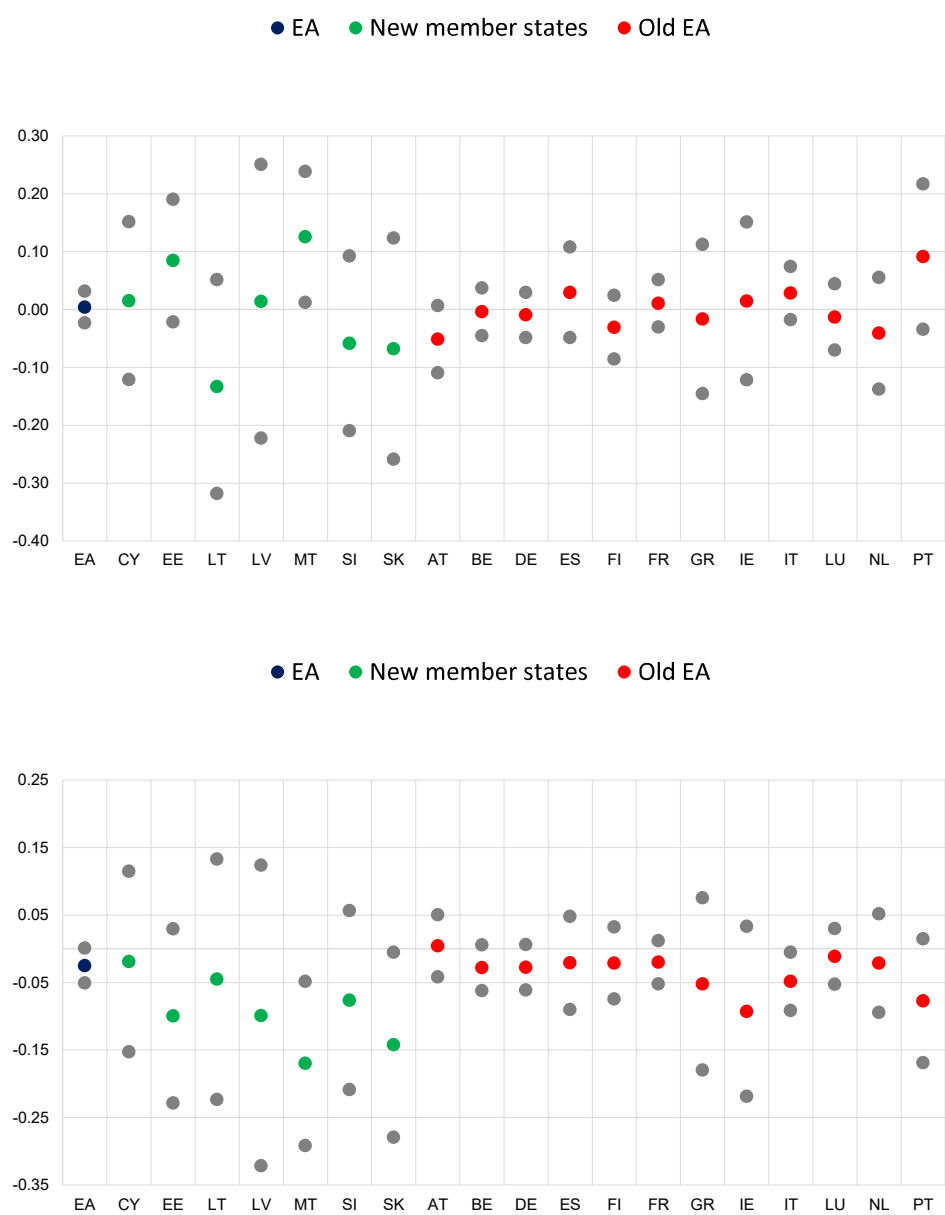
(Local projections. Median values with 95% bands. Results across BVAR models. Q1)

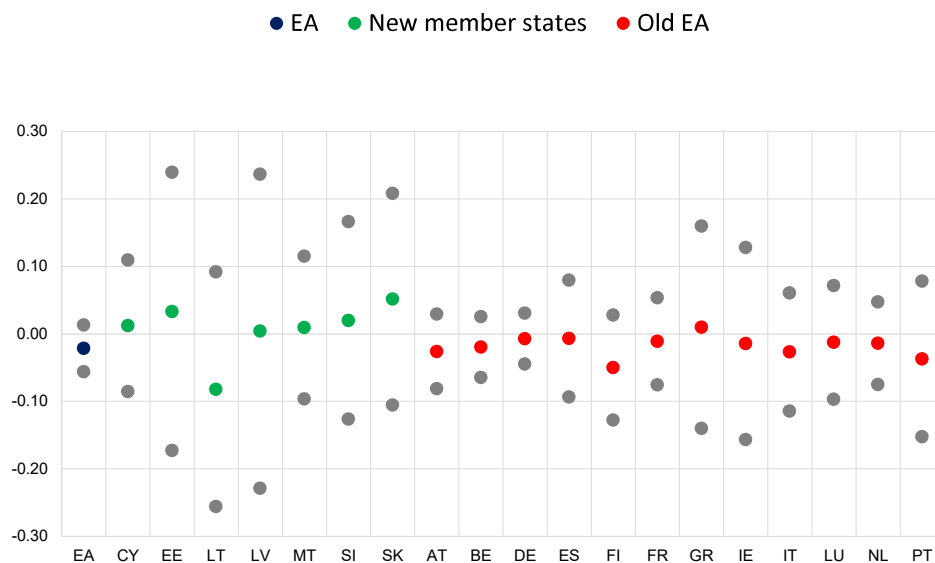


Note: Forbes refers to Forbes et al. (2018) identification, CK is Comunale and Kunovac (2017), BdE is Leiva-Leon et al. (2018), BdI is Conti et al. (2017) and PAC is Montes-Galdon et al. (2019). BVARs considered are CK, Forbes, BdE and BdI. Forbes, BdI and CK use NEER-38, BdE instead includes EURUSD. Data are until 2019Q1, except for US MP which comes from PAC and with data until 2017Q4.

**Chart A.7: (Relative) monetary policy shock (HICPX)**

(Local projections. Median values with 95% bands. Results across BVAR models. Chart (a) is on relative MP, chart (b) about EA MP and chart (c) on US MP. Q1)

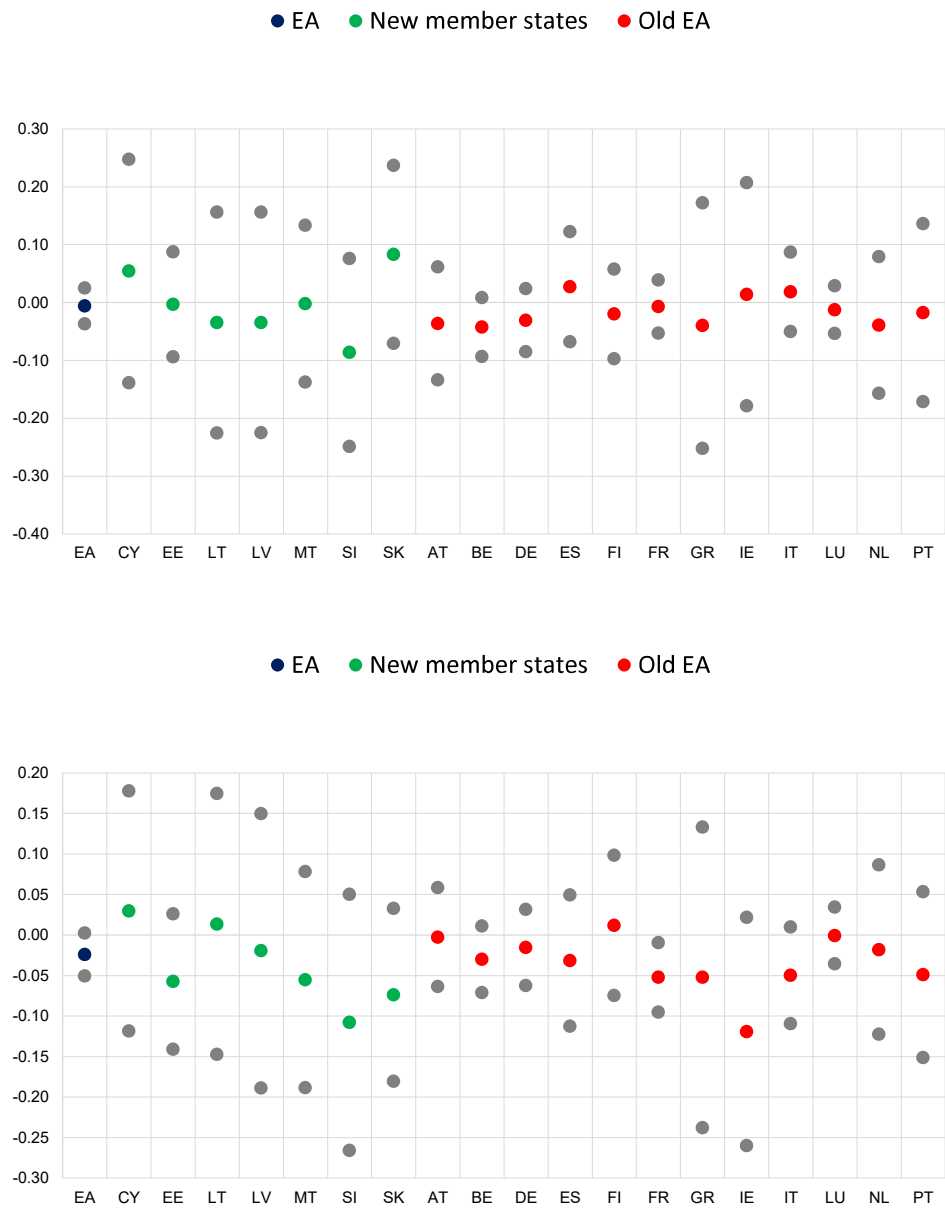


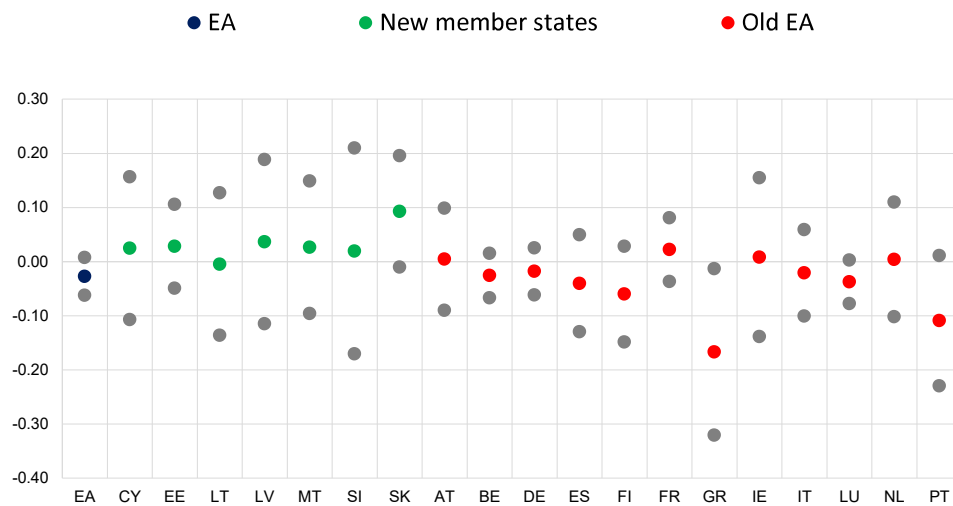


Note: Forbes refers to Forbes et al. (2018) identification, CK is Comunale and Kunovac (2017), BdE is Leiva-Leon et al. (2018), BdI is Conti et al. (2017) and PAC is Montes-Galdon et al. (2019). BVARs considered are CK, Forbes, BdE and BdI. CK and BdE have relative monetary policy. The others use only EA monetary policy. Data are until 2019Q1, except for US MP which comes from PAC and with data until 2017Q4.

**Chart A.8: (Relative) monetary policy shock (NEIG)**

(Local projections. Median values with 95% bands. Results across BVAR models. Chart (a) is on relative MP, chart (b) about EA MP and chart (c) on US MP. Q1)

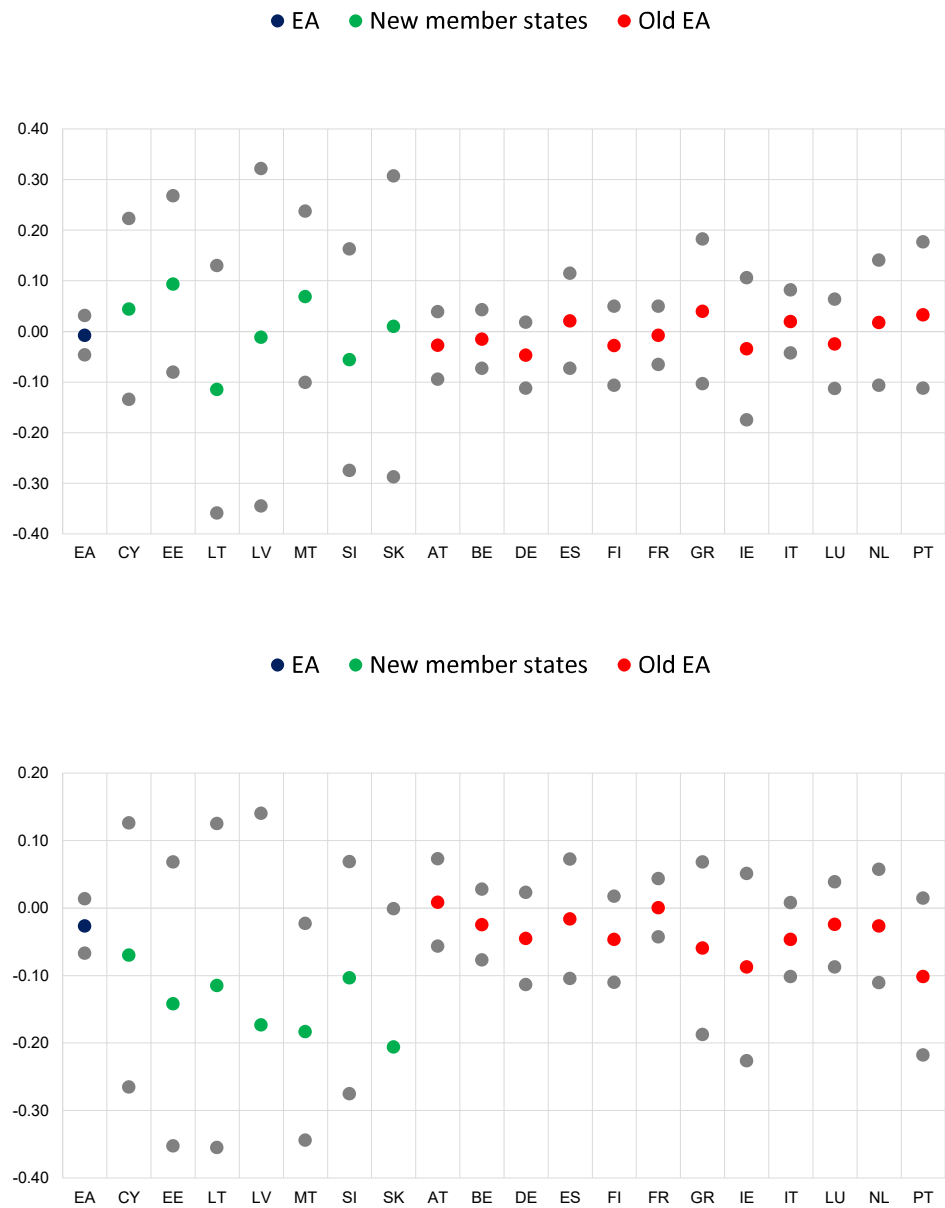




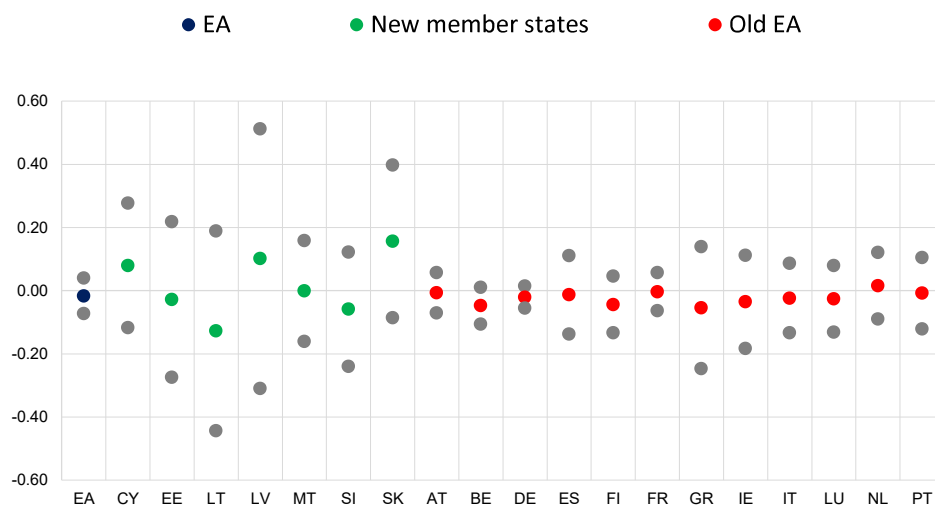
Note: Forbes refers to Forbes et al. (2018) identification, CK is Comunale and Kunovac (2017), BdE is Leiva-Leon et al. (2018), BdI is Conti et al. (2017) and PAC is Montes-Galdon et al. (2019). BVARs considered are CK, Forbes, BdE and BdI. CK and BdE have relative monetary policy. The others use only EA monetary policy. Data are until 2019Q1, except for US MP which comes from PAC and with data until 2017Q4.

**Chart A.9: (Relative) monetary policy shock (SERV)**

(Local projections. Median values with 95% bands. Results across BVAR models. Chart (a) is on relative MP, chart (b) about EA MP and chart (c) on US MP. Q1)







Note: Forbes refers to Forbes et al. (2018) identification, CK is Comunale and Kunovac (2017), BdE is Leiva-Leon et al. (2018), BdI is Conti et al. (2017) and PAC is Montes-Galdon et al. (2019). BVARs considered are CK, Forbes, BdE and BdI. CK and BdE have relative monetary policy. The others use only EA monetary policy. Data are until 2019Q1, except for US MP which comes from PAC and with data until 2017Q4.

#### **Appendix IV: The impact of exchange rate shocks on real GDP growth**

In this section, we look at impact of exchange rate shocks on real GDP growth. We analyse what is the contribution of identified shocks, including exchange rate shocks, on changes in real GDP in the historical decompositions and whether this pass-through to real activity is heterogeneous across euro area countries. We found that the impact of exchange rate shocks is less evident than in prices and that there could be more homogeneity between old and new countries in the euro area.

In general, there is little to no consensus for GDP across models. In both BVARs and DSGEs, the exogenous exchange rate shocks explain a very small percentage of the change in GDP. In the historical decomposition in Comunale and Kunovac (2017) the global supply shock is actually the main factor to explain changes in real GDP while, using the identification as in Forbes et al. (2018), most of the variation in GDP, both during the APP announcement and the recent quarters, is explained by euro area supply shocks. In the DSGE model also, aggregate supply plays a significant role in changes in real GDP during the APP announcement period. In Chart A.10 we provide the historical decomposition of GDP in the considered models. It is important to note that in the DSGE, the data refer to q-o-q growth rate in the real GDP per capita and the de-meanned variable is reported originally and in Figure A.10.<sup>39</sup>

Looking now at the possible heterogeneity across member states in responses to the common shocks identified in the BVARs, the differences between new and old members seem less evident than in the case of inflation. For exogenous exchange rate shocks in the first quarters, the higher median values found in the BVAR have been experienced in Spain, Finland and Estonia while the lowest were in the Netherlands, Malta, Cyprus and Ireland. For domestic monetary policy, we see the largest impact in Germany, Finland, Portugal, Spain and Estonia, all above 0.3. For relative monetary policy, the sign of the responses is very heterogeneous across countries and mostly negative in old member states. There is, however, a wide variation of estimates across models and the results do not look significant within 95% confidence intervals. The variation across estimates are smaller in the case of inflation.

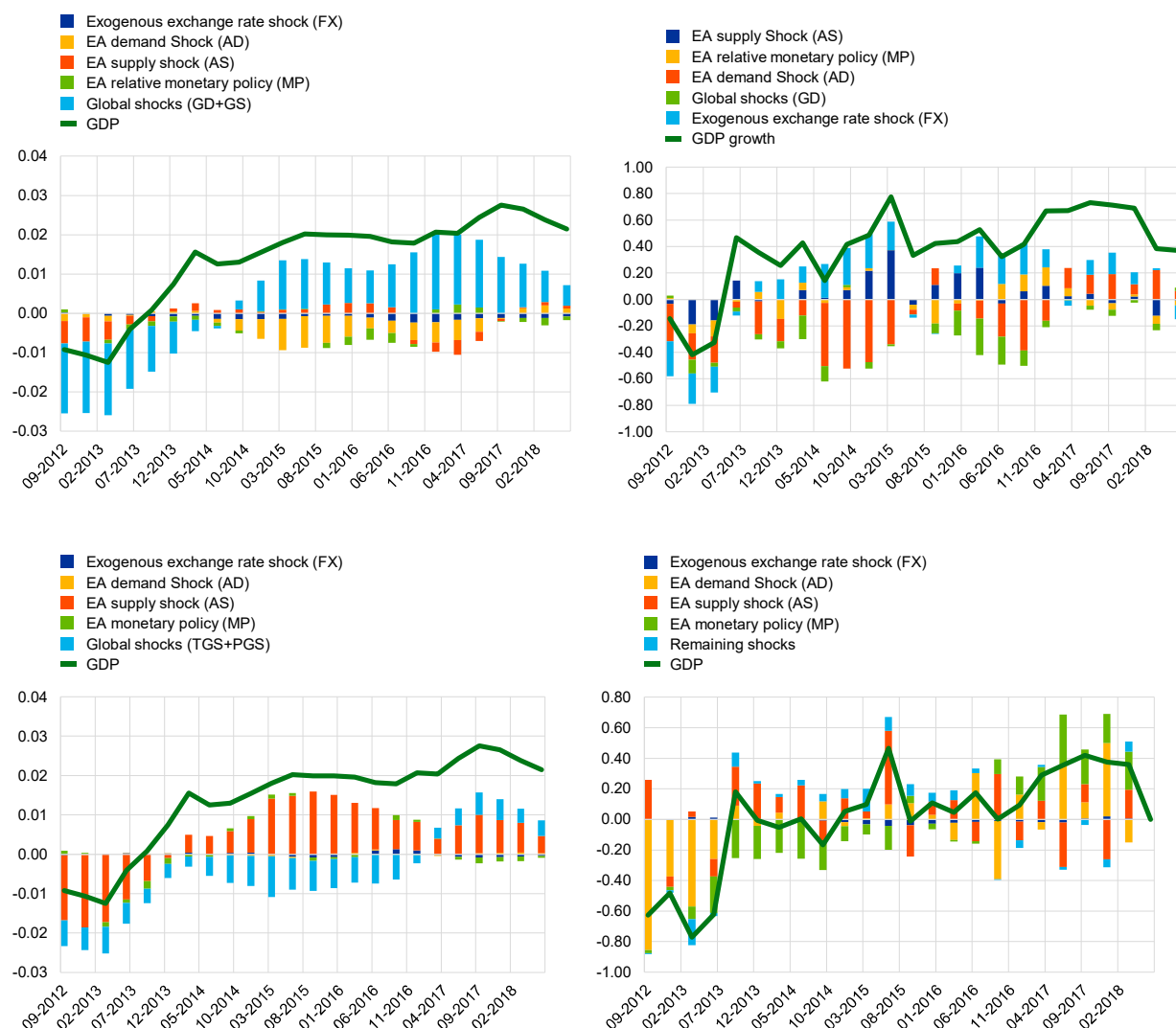
Lastly, we provide the shock dependent pass-through in the case of real GDP (Table A.1). Also in this case, there is little to no consensus across BVARs and between BVARs and DSGEs.

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<sup>39</sup> More precisely in this DSGE:  $dPCD = 100 * \ln(PCD_t / PCD_{t-1}) - 0.4582$   
 $dYER = 100 * \ln((YER_t / Pop_t) / (YER_{t-1} / Pop_{t-1})) - 0.3087$

### Chart A.10: GDP shocks decomposition BVARs (CK vs. BdE vs. Forbes) and NBB DSGE

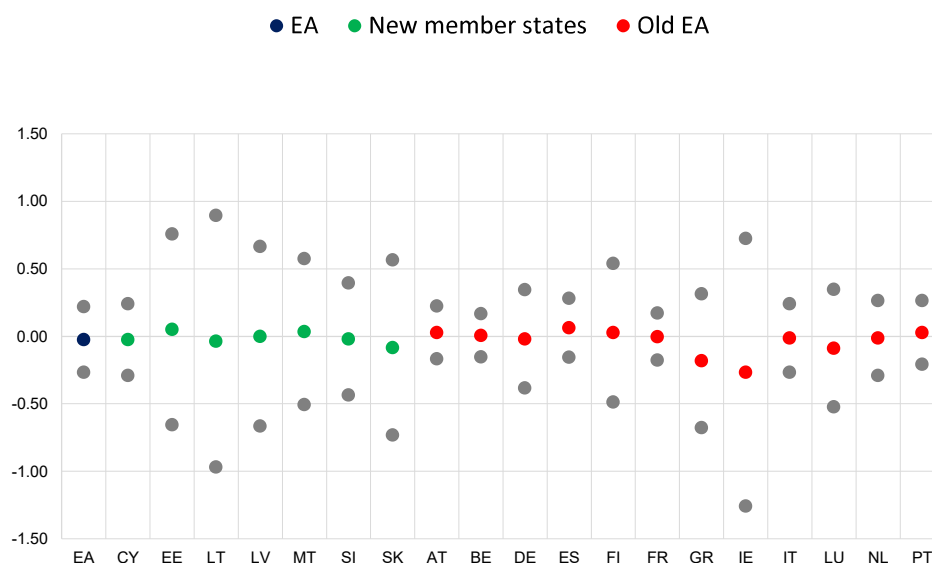
(Data from 2012Q3 to 2018Q2 or Q3 – NEER-38 for CK (LHS) and Forbes (below LHS), EURUSD for BdE (RHS) and DSGE (below RHS))



Note: Forbes refers to Forbes et al. (2018) identification, CK is Comunale and Kunovac (2017), BdE is Leiva et al. (2020). In case of DSGE is taken in deviation from the mean and relative to population:  $dYER = 100 * \ln(YER_t / Pop_t) / (YER_{t-1} / Pop_{t-1}) - 0.3087$ .

### Chart A.11: The response to exchange rate shocks (real GDP)

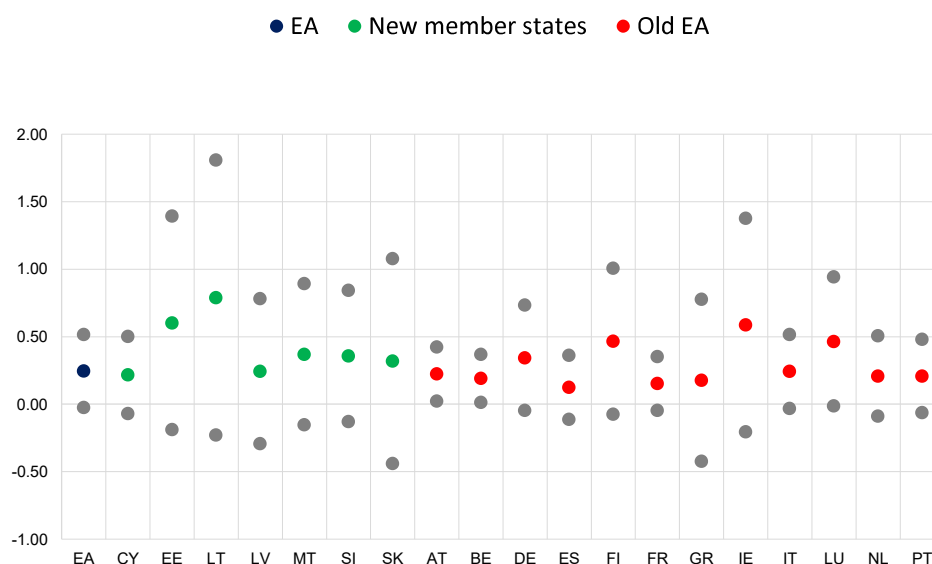
(Local projections. Median values with 95% bands. Results across BVAR models. Q1)

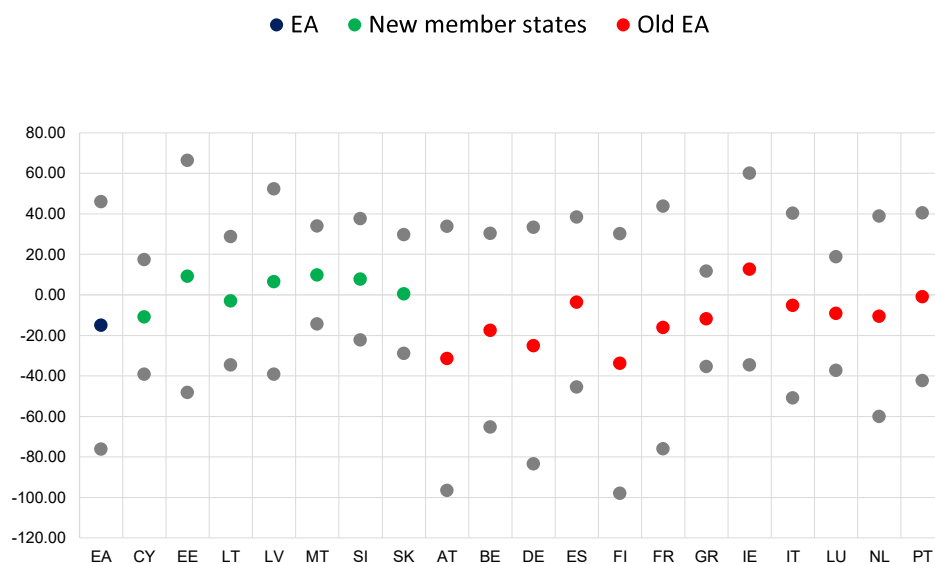
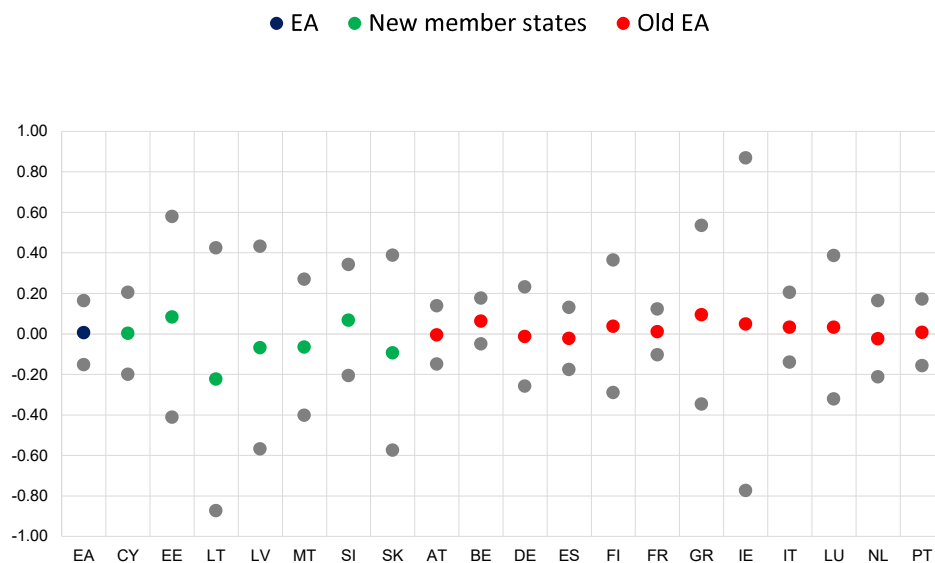


Note: Forbes refers to Forbes et al. (2018) identification, CK is Comunale and Kunovac (2017), BdE is Leiva-Leon et al. (2018), BdI is Conti et al. (2017) and PAC is Montes-Galdon et al. (2019). BVARs considered are CK, Forbes, BdE and BdI. Forbes, BdI and CK use NEER-38, BdE instead includes EURUSD. Data are until 2019Q1, except for US MP which comes from PAC and with data until 2017Q4.

### Chart A.12: (Relative) monetary policy shock (real GDP)

(Local projections. Median values with 95% bands. Results across BVAR models. Chart (a) is on relative MP, chart (b) about EA MP and chart (c) on US MP. Q1)





Note: Forbes refers to Forbes et al. (2018) identification, CK is Comunale and Kunovac (2017), BdE is Leiva-Leon et al. (2018), BdI is Conti et al. (2017) and PAC is Montes-Galdon et al. (2019). BVARs considered are CK, Forbes, BdE and BdI. CK and BdE have relative monetary policy. The others use only EA monetary policy. Data are until 2019Q1, except for US MP which comes from PAC and with data until 2017Q4.

**Table A.1: Empirical estimates for shock-dependent ERPT to real GDP in the euro area**

(Impact after Q1-Q12 of 1% depreciation in exchange rate (NEER or EURUSD))

Shocks	Horizons	Median DSGEs	Median BVARs	Forbes	CK	BdE	BdI
Exogenous exchange rate	Q1	0.03	0.33	-0.05	0.64	0.02	3.04
	Q4	0.03	0.25	-0.06	0.43	0.06	1.50
	Q8	0.02	0.25	-0.05	0.40	0.09	0.96
	Q12	-0.09	0.24	-0.04	0.37	0.12	0.72
Domestic demand	Q1	-0.84	0.10	0.06	-0.24	0.14	0.18
	Q4	0.89	0.11	0.08	-0.30	0.14	0.22
	Q8	0.62	0.08	0.06	-0.27	0.09	0.36
	Q12	0.36	0.04	0.05	-0.23	0.04	0.52
Monetary policy	Q1	0.27	0.03	-0.05	0.18	-0.01	0.06
	Q4	0.65	0.05	-0.02	0.12	0.01	0.09
	Q8	0.53	0.05	-0.01	0.09	0.01	0.09
	Q12	0.35	0.04	-0.01	0.08	0.01	0.12
Domestic supply	Q1	0.99	-0.01	0.27	0.09	-0.12	-0.24
	Q4	0.85	0.00	0.38	0.12	-0.13	-0.25
	Q8	1.17	-0.03	0.36	0.11	-0.16	-0.22
	Q12	-0.50	-0.05	0.34	0.07	-0.18	-0.17

Note: Impact after Q1-Q12 of 1% depreciation in exchange rate (NEER or EURUSD). Forbes refers to Forbes et al. (2018) identification, CK is Comunale and Kunovac (2017), BdE is Leiva et al. (2020), BdI is Conti et al. (2017). Forbes, BdI and CK use NEER-38, BdE instead includes EURUSD. Monetary policy is taken in relative terms with respect to the US in CK and BdE. Data points until 2019Q1 (or Q2). In the models, when included, import prices are total prices for BVARs and extra-EA prices in the DSGEs. For the latter, the exception is the model by Bank of Finland, which applies total import prices. The model by the Bank of Finland is not included in the results in this table for the supply shock.