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Working Paper

Introducing dominant currency pricing in the ECB's global macroeconomic model

ECB Working Paper, No. 2321

Provided in Cooperation with:

European Central Bank (ECB)

Suggested Citation: Georgiadis, Georgios; Möhle, Saskia (2019) : Introducing dominant currency pricing in the ECB's global macroeconomic model, ECB Working Paper, No. 2321, ISBN 978-92-899-3890-7, European Central Bank (ECB), Frankfurt a. M., <https://doi.org/10.2866/879528>

This Version is available at:

<https://hdl.handle.net/10419/208355>

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EUROPEAN CENTRAL BANK

EUROSYSTEM

Working Paper Series

Georgios Georgiadis, Saskia Möhle Introducing dominant currency pricing in the ECB's global macroeconomic model

No 2321 / October 2019

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Abstract

A large share of global trade being priced and invoiced primarily in US dollar rather than the exporter's or the importer's currency has important implications for the transmission of shocks. We introduce this “dominant currency pricing” (DCP) into ECB-Global, the ECB's macroeconomic model for the global economy. To our knowledge, this is the first attempt to incorporate DCP into a major global macroeconomic model used at central banks or international organisations. In ECB-Global, DCP affects in particular the role of expenditure-switching and the US dollar exchange rate for spillovers: In case of a shock in a non-US economy that alters the value of its currency multilaterally, expenditure-switching occurs only through imports; in case of a US shock that alters the value of the US dollar multilaterally, expenditure-switching occurs both in non-US economies' imports and — as these are imports of their trading partners — exports. Overall, under DCP the US dollar exchange rate is a major driver of global trade, even for transactions that do not involve the US. In order to illustrate the usefulness of ECB-Global and DCP for policy analysis, we explore the implications of the euro rivaling the US dollar as a second dominant currency in global trade. According to ECB-Global, in such a scenario the global spillovers from US shocks are smaller, while those from euro area shocks are amplified; domestic euro area monetary policy effectiveness is hardly affected by the euro becoming a second globally dominant currency in trade.

Keywords: Global macroeconomic modelling, dominant currency paradigm, spillovers.

JEL-Classification: F42, E52, C50.

Non-technical summary

Academic research has recently highlighted the role of dominant-currency pricing (DCP) for the domestic and cross-border transmission of shocks. Traditionally, open economy models assume that exports are priced and invoiced in the currency of the producer, i.e. producer-currency pricing (PCP), or in the currency of the destination, i.e. local-currency pricing (LCP). In contrast, the data suggest that a large share of trade is invoiced in a few dominant currencies. In particular, the data displayed in Figure 1 document that a large share of global trade is invoiced in US dollar. This is the case in particular for emerging market economies (EMEs), and notably for transactions that do not involve the US as a trading partner. DCP has important implications for the dynamics of trade variables that differ from those under PCP and LCP. For example, in case of a multilateral appreciation of the Home currency driven by a contractionary monetary policy shock, Home terms-of-trade are stable as import and export prices both fall in Home currency terms. This is in contrast to PCP, under which the terms-of-trade rise as Home import prices fall while Home export prices are constant; and this is also in contrast to LCP, under which the terms-of-trade fall, as Home import prices in domestic currency are constant while Home export prices in domestic currency fall. In turn, the differential responses of the terms-of-trade imply differences in the role of expenditure switching in case of a multilateral appreciation of the Home currency driven by a contractionary monetary policy shock. Specifically, under DCP expenditure switching occurs through imports alone. In contrast, under PCP expenditure switching occurs through both imports and exports, and under LCP expenditure switching is muted overall. Moreover, under DCP the US dollar is the major driver of global trade, in contrast to the cases of PCP and LCP. Specifically, a multilateral appreciation of the US dollar reduces imports — and thereby exports — globally, even for transactions that do not involve the US as a trading partner. In this paper, we document the introduction of DCP into ECB-Global, the ECB's main global macroeconomic model. To the best of our knowledge, this is the first attempt of introducing DCP into a major global macroeconomic model used at policy institutions. We document that while introducing DCP into ECB-Global does not imply economically significant changes in the dynamics of domestic macroeconomic and financial variables in response to standard shocks, it does imply important changes in the dynamics of imports and exports, the role of expenditure switching and the US dollar exchange rate therein. Finally, in order to illustrate the usefulness of ECB-Global and DCP for policy analysis, we explore the implications of the Euro rivaling the US dollar as a second dominant currency in global trade. We document that according to ECB-Global, in such a shared DCP scenario the global spillovers from US shocks are smaller, while those from euro area shocks are amplified. In contrast, domestic euro area monetary policy effectiveness is hardly affected by the Euro becoming a second globally dominant currency in trade.

1 Introduction

In an increasingly integrated global economy, spillovers and the interdependence of economic policies have gained immense prominence among commentators. Consequently, there has been a growing interest in the use of global macroeconomic models which incorporate rich transmission channels of cross-border spillovers for scenario analyses and forecasting. This is also true for central banks, which increasingly recognise the importance of the global economy for the evolution of the domestic economy. And especially for major central banks, it has been increasingly recognised that it is important to account for the effects of domestic monetary policy on the rest of the world. For example, at the IMF the Flexible System of Global Models (Andrle et al.; 2015) and the Global Integrated Monetary and Fiscal (Laxton and Kumhof; 2007) model have been used extensively for simulations underpinning the World Economic Outlook; at the ECB, ECB-Global (Dieppe et al.; 2017) regularly provides insights from scenario analyses in different contexts.

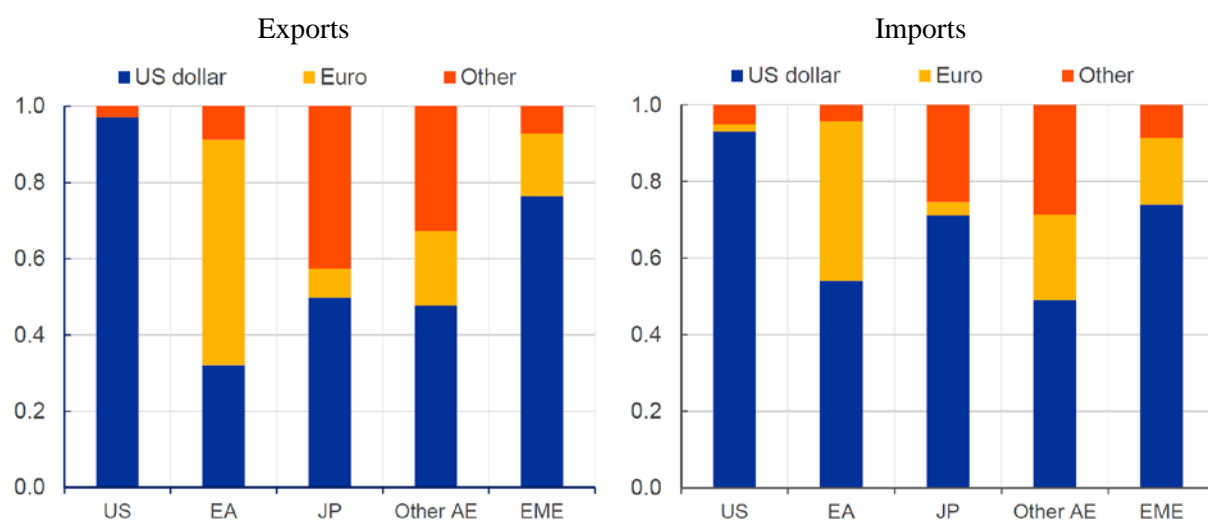
In parallel, academic research has recently highlighted the role of dominant-currency pricing (DCP) for the domestic and cross-border transmission of shocks. Traditionally, open-economy models assume that exports are priced and invoiced in the currency of the producer, i.e., producer-currency pricing (PCP), or in the currency of the destination, i.e., local-currency pricing (LCP). In contrast, the data suggest that a large share of trade is invoiced in a few dominant currencies (Gopinath; 2015).¹ In particular, the data displayed in Figure 1 document that a large share of global trade is invoiced in US dollars. This is the case in particular for emerging market economies (EMEs), and notably for transactions that do not involve the US as a trading partner. Moreover, Gopinath and Rigobon (2008), Fitzgerald and Haller (2012), Chen et al. (2018), and Georgiadis and Schumann (2019) provide evidence that export and import prices are sticky in the invoicing currency.

DCP has important implications for the dynamics of trade variables that differ from those under PCP and LCP. Specifically, Casas et al. (2017) consider a three-country New Keynesian dynamic stochastic general equilibrium (NK DSGE) model for the Home economy, the rest of the world (RoW) and the US in which export prices are sticky in US dollars. In their model, in the case of a multilateral appreciation of the Home-currency driven by a contractionary monetary policy shock, Home terms-of-trade are stable as import and export prices both fall in Home currency terms. This is in contrast to PCP, under which the terms-of-trade rise as Home import prices fall while Home export

¹ Seminal contributions in the context of PCP include Fleming (1962), Mundell (1963), as well as Obstfeld and Rogoff (1995). Seminal contributions on LCP include Betts and Devereux (2000) and Devereux and Engel (2003). See Corsetti and Pesenti (2005) for a discussion of differences in the implications of PCP and LCP.

prices are constant; and this is also in contrast to LCP, under which the terms-of-trade fall as Home import prices in domestic currency remain constant while Home export prices in domestic currency fall. In turn, the differential responses of the terms-of-trade imply differences in the role of expenditure-switching in case of a multilateral appreciation of the Home currency driven by a contractionary monetary policy shock. Specifically, under DCP, expenditure-switching occurs through imports alone.

Figure 1: Distribution of invoicing currencies in the data



Note: The left-hand side panel displays the values for the shares of economy's exports invoiced in domestic currency and US dollar, respectively. The right-hand side panel displays the values of the shares of economy's imports invoiced in US dollars and the producers' currencies, respectively. The data are taken from Gopinath (2015) and Eurostat for the euro area, which refer to extra-EU exports. Data for country groups are aggregated from country-specific data using shares in global imports as weights.

In contrast, under PCP, expenditure-switching occurs through both imports and exports, and under LCP, expenditure-switching is muted overall. Moreover, in a similar model environment, Boz et al. (2017) show that under DCP, the US dollar is the major driver of global trade, in contrast to the cases of PCP and LCP.² Specifically, a multilateral appreciation of the US dollar reduces imports — and thereby exports — globally, even for transactions that do not involve the US as a trading partner.

A quick look at the data confirms these predictions from DCP. Specifically, Table 1 reports results from regressions of exports and imports on the local and the US dollar real effective exchange rates as well as (trading-partner) real GDP growth.³ The results suggest that for EMEs an appreciation of the

² Zhang (2018) also studies the role of dominant currency pricing for US monetary policy spillovers.

³ The import and export data for the regressions stem from the IMF's World Economic Outlook database, and the real effective exchange rate data are taken from the IMF's International Financial Statistics. Trading-partner real GDP growth is constructed as a trade-weighted average. The frequency of the data is yearly, and the sample period spans 1999 to 2017. The set of advanced economies includes Australia, Austria, Belgium, Canada, Cyprus, Denmark, Finland, France, Germany, Ireland, Iceland, Italy, Japan, Luxembourg, Malta, Netherlands, Norway, New Zealand, Portugal, Spain, Sweden,

local exchange rate increases imports. In contrast, a multilateral appreciation of the US dollar reduces EME imports, regardless of the fact that a large share of these imports do not originate in the US. For advanced economies, whose imports are to a larger extent invoiced in the producer's currency, only an appreciation of the local exchange rate affects imports. In contrast to import growth, export growth in EMEs is exclusively driven by the US dollar real effective exchange rate. In advanced economies, which invoice a larger share of exports in the producer's currency, again only the local exchange rate drives exports.

Table 1: Regression results for import/export growth on domestic and US real effective exchange rates

	Import growth		Export growth	
	(1) AEs	(2) EMEs	(3) AEs	(4) EMEs
Change in local REER (+ local appreciation)	0.109*** (0.00)	0.126** (0.02)	-0.165** (0.02)	-0.036 (0.37)
Change in USD REER (+ USD appreciation)	-0.160 (0.21)	-0.259** (0.03)	0.010 (0.83)	-0.150** (0.01)
Real GDP growth	1.702*** (0.00)	1.596*** (0.00)		
Trading-partner real GDP growth			2.550*** (0.00)	1.668*** (0.00)
R-squared (within)	0.45	0.29	0.50	0.14
Observations	430	1076	434	1156
Countries	23	72	23	72

Driscoll-Kraay robust standard errors.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

More rigorous and systematic empirical evidence available in the literature is also consistent with the predictions from DCP. In particular, Casas et al. (2017) provide evidence that is consistent with the predictions from DCP based on micro-data on trade for Colombia. Specifically, Casas et al. (2017) document economically and statistically significant estimates of the pass-through of variations in the bilateral exchange rate of the Colombian peso against the US dollar to Colombian export and import prices in peso terms. Importantly, when controlling for the bilateral exchange rate of the peso against the US dollar, the estimate of the pass-through of variations in the bilateral exchange rate of the peso against the currency of the export destination/import origin is neither economically nor statistically significant.⁴

Switzerland, and the UK; all remaining economies are labelled as EMEs. In order to preclude that outlier observations are driving the estimates, we drop observations in which the real effective exchange rate, imports or exports change annually by more than 25% in absolute terms, and (trading-partner) real GDP growth by more than 10% in absolute terms. Finally, and as suggested by a referee, in order to preclude estimates being driven by very small economies, observations are weighted by economies' GDP.

⁴ Chen et al. (2018) report similar findings for UK data.

Moreover, Casas et al. (2017) document that Colombian export and import quantities respond to variations in the bilateral exchange rate of the peso against the US dollar regardless of the trading partner, but not to variations in the bilateral exchange rate of the peso against the currency of the trading partner. Boz et al. (2017) generalise these findings examining a bilateral dataset on trade flows and prices for 55 economies. And Boz et al. (2017) also provide evidence that a multilateral appreciation of the US dollar reduces trade globally, even for trade relationships that do not involve the US.

DCP thus seems to be an important feature of the world economy that should be taken into account in models used for policy recommendations. In this paper, we document the introduction of DCP into ECB-Global, the ECB's main global macroeconomic model. The baseline version of ECB-Global described in Dieppe et al. (2017) assumes PCP. To the best of our knowledge, this is the first attempt to introduce DCP into a major global macroeconomic model used at policy institutions. We document that while introducing DCP into ECB-Global does not imply economically significant changes in the dynamics of domestic macroeconomic and financial variables in response to standard shocks, it does imply important changes in the dynamics of imports and exports, the role of expenditure-switching, and the US dollar exchange rate therein. The findings are consistent with those in Casas et al. (2017) as well as Boz et al. (2017). Specifically, in ECB-Global under DCP, in the case of shocks that appreciate a non-US currency multilaterally, expenditure-switching occurs mainly through imports rather than through exports. Moreover, DCP in ECB-Global implies that global trade is substantially more sensitive to US shocks that change the US dollar exchange rate multilaterally than under PCP. Finally, in order to illustrate the usefulness of ECB-Global and DCP for policy analysis, we explore the implications of the euro rivaling the US dollar as a second dominant currency in global trade. We document that according to ECB-Global, in such a shared DCP scenario the global spillovers from US shocks are smaller, while those from euro-area shocks are amplified. In contrast, domestic euro area monetary policy effectiveness is hardly affected by the euro becoming a second globally dominant currency in trade.

The rest of the paper proceeds as follows. In Section 2, we briefly review ECB-Global and describe how we introduce DCP. In Section 3, we discuss the responses of domestic variables and trade to monetary policy shocks in emerging (EM) Asia, the US, and the euro area, comparing those from the baseline version of ECB-Global with PCP to those from the version with DCP. In Section 4, we explore a scenario in which the euro rivals the US dollar as a second dominant currency in global

trade. Finally, Section 5 concludes.

2 Introducing DCP in ECB-Global

2.1 Background on ECB-Global

There is a growing literature on the advantages of semi-structural approaches in macro-modelling, especially for policy institutions where set-ups need to be particularly flexible in order to be able to address quickly evolving issues (see, for example, McKibbin and Stoeckel; 2017; Hendry and Muellbauer; 2017). In line with this rationale, the development of ECB-Global follows a semi-structural approach, combining the advantages of fully structural models with those of models composed of reduced-form equations. The evolution of the economies in ECB-Global is determined by a set of core structural relationships (e.g., Phillips and IS curves). The advantage of the structural elements of ECB-Global is that shocks have a structural economic interpretation, and that it facilitates tracking their domestic and international transmission. Second, reduced-form equations are added to enrich the core of ECB-Global. The advantage of the reduced-form aspects of ECB-Global is that they facilitate modifying the model in a flexible manner so that it can be adapted relatively easily. Moreover, the addition of the reduced-form elements improves the empirical fit of ECB-Global. As a result, ECB-Global is a rich semi-structural, multi-country model featuring diverse real and financial cross-border spillover channels for the euro area, the US, Japan, the UK, China, the rest of Emerging (EM) Asia, oil-producing economies, and the rest of the world. ECB-Global is similar in spirit to other semi-structural models that have recently become popular at central banks and international organisations, such as the IMF's Global Projection Model (GPM; Blagrove et al.; 2013) and Flexible System of Global Models (FSGM; Andrieu et al.; 2015), the Bank of England's COMPASS model (Burgess et al.; 2013), and the Reserve Bank of New Zealand's NZSIM (Kamber et al.; 2016).

In order to assess the implications of the special role of the US dollar in trade for spillovers, in this paper, we modify the baseline version of ECB-Global to incorporate DCP. Specifically, we introduce DCP along with PCP by assuming that a share of an economy's exports is invoiced in US dollars, rather than in the exporter's currency alone. This assumption implies that also a share of an economy's imports is priced in US dollars. We also assume that the prices of exports that are invoiced in US dollars are also sticky in US dollars. For the sake of parsimony, in the following we do not state all equations that define ECB-Global, but report only those that are different or new relative to the baseline version of ECB-Global due to the introduction of DCP. For details on the remaining parts of

the model description we refer the reader to Dieppe et al. (2017). Also for the sake of parsimony, and as in Dieppe et al. (2017), in describing the model equations, we only report the equations for the euro area.⁵ Finally, and again for the sake of parsimony, when stating the model equations we act as if ECB-Global included only the euro area, the US, and EM Asia.

2.2 Trade

Euro-area demand for bilateral (non-oil) imports from EM Asia under the baseline version of PCP in ECB-Global is given by

$$m_{ea,as,t}^{nonoil,pcp} = \left(\frac{S_{ea,t} P_{as,t}^{ppi}}{S_{as,t} P_{ea,t}^{cpi}} \right)^{-\theta_{ea}^{nonoil}} da_{ea,t}, \quad (1)$$

where P_{it}^{ppi} is the price of domestic output, P_{it}^{cpi} represents consumer prices, da_{it} is domestic absorption, and S_{it} is the nominal bilateral exchange rate between the currency of country i and the US dollar; S_{it} is defined such that an increase reflects a depreciation of the currency of country i against the US dollar. We introduce DCP by modifying the specification of import demand in Equation (1) as

$$m_{ea,as,t}^{nonoil,dcp} = \left(\frac{S_{ea,t} P_{as,t}^{x dcp}}{P_{ea,t}^{cpi}} \right)^{-\theta_{ea}^{nonoil}} da_{ea,t}, \quad (2)$$

where $P_{it}^{x dcp}$ represents DCP export prices that will be defined below. DCP is reflected in the assumption that export prices are quoted in US dollars, and that they are also sticky in US dollars. In principle, DCP as introduced in Equation (2) can be generalised to several dominant currencies. This may be useful for a version of ECB-Global that features Central and Eastern European economies, which invoice a large share of exports in euros rather than in US dollars. Below, we consider a shared DCP scenario in which the euro rivals the US dollar as a second global dominant currency.

The euro area's total non-oil imports are then given by

$$P_{ea,t}^{m nonoil} \cdot m_{ea,t}^{nonoil} = S_{ea,t} P_{us,t}^{ppi} \cdot m_{ea,us,t}^{nonoil} \quad (3)$$

⁵ In particular, the US, Japan, the UK, EM Asia, and the rest of the world are modelled symmetrically to the euro area. Only China and the oil-producing country block differ in structure. Specifically, China features a different monetary policy rule and uncovered interest rate parity condition, and the oil-producing countries differ in that they receive oil export revenues, which in turn determine government expenditures.

$$+ \frac{S_{ea,t}}{S_{as,t}} P_{as,t}^{ppi} \cdot m_{ea,as,t}^{nonoil,pcp} + S_{ea,t} P_{as,t}^{x^{dcp}} \cdot m_{ea,as,t}^{nonoil,dcp}.$$

$P_{it}^{m^{nonoil}}$ represents a non-oil import-price index given by

$$P_{ea,t}^{m^{nonoil}} = \sum_j \omega_{ea,j}^{M^{nonoil}} \left[\delta_j^{dcp} (S_{ea,t} P_{j,t}^{x^{dcp}}) + (1 - \delta_j^{dcp}) \left(\frac{S_{ea,t}}{S_{j,t}} P_{j,t}^{ppi} \right) \right], \quad (4)$$

where δ_j^{dcp} denotes the steady-state share of economy j 's exports subject to DCP, and $\omega_{ea,j}^{M^{nonoil}}$ the steady-state share of the euro area's total non-oil imports accounted for by trading partner j . In turn, the euro area's total imports — i.e., non-oil and oil imports — are given by

$$P_{ea,t}^m \cdot m_{ea,t} = P_{ea,t}^{m^{nonoil}} \cdot m_{ea,t}^{nonoil} + S_{ea,t} P_t^{oil} \cdot m_{ea,t}^{oil}, \quad (5)$$

where P_t^{oil} is the price of oil quoted in US dollars. The total import-price index P_{it}^m is given by

$$P_{ea,t}^m = (1 - \zeta_{ea}^{oil}) P_{ea,t}^{m^{nonoil}} \cdot \zeta_{ea}^{oil} (S_{ea,t} P_t^{oil}), \quad (6)$$

where ζ_{ea}^{oil} represents the steady-state share of oil imports in total euro area imports.

With DCP, the euro area's exports are given by the sum of its exports priced in Euro and those priced in US dollars, i.e.,

$$P_{ea,t}^x \cdot x_{ea,t} = S_{ea,t} P_{ea,t}^{x^{dcp}} \cdot x_{ea,t}^{dcp} + P_{ea,t}^{ppi} \cdot x_{ea,t}^{pcp}, \quad (7)$$

where the export-price index P_{it}^x is given by

$$P_{ea,t}^x = \delta_{ea}^{dcp} (S_{ea,t} P_{ea,t}^{x^{dcp}}) + (1 - \delta_{ea}^{dcp}) P_{ea,t}^{ppi}. \quad (8)$$

Even though this is not a new element in ECB-Global that arises under DCP, it is worthwhile to recall that in order to achieve global consistency of trade, an economy's exports in ECB-Global are defined as the sum of its trading partners' bilateral imports, i.e.,

$$X_{ea,t}^j = M_{us,ea,t}^{nonoil} + M_{as,ea,t}^{nonoil,j}, \quad j \in \{dcp, pcp\}, \quad (9)$$

where uppercase letters for stock or flow variables refer to aggregate values, in contrast to lowercase letters, which denote variables in per capita terms.

Against the background of the implications of DCP for the dynamics of global trade discussed in the Introduction, it is also worthwhile to define global imports as

$$P_t^m \cdot M_t = P_{us,t}^m \cdot M_{us,t} + \frac{P_{ea,t}^m}{S_{ea,t}} \cdot M_{ea,t} + \frac{P_{op,t}^m}{S_{op,t}} \cdot M_{op,t}, \quad (10)$$

with the global import-price index

$$P_t^m = \sum_j \chi_j \left(\frac{P_{j,t}^m}{S_{j,t}} \right), \quad (11)$$

where χ_j represents country j 's steady-state share in global imports. In turn, global exports are given by

$$P_t^x \cdot X_t = P_{us,t}^x \cdot X_{us,t} + \frac{P_{ea,t}^x}{S_{ea,t}} \cdot X_{ea,t} + \frac{P_{op,t}^x}{S_{op,t}} \cdot X_{op,t}, \quad (12)$$

with the global export-price index

$$P_t^x = \sum_j \chi_j \left(\frac{P_{j,t}^x}{S_{j,t}} \right), \quad (13)$$

where χ_j represents country j 's steady-state share in global exports. Notice that because of balanced trade at the country level in the steady state, country j 's steady-state share in global exports equals its share in global imports.

Assuming export prices are sticky in US dollars, the evolution of export-price inflation is determined by a Phillips-curve given by

$$\pi_{ea,t}^{x, dcp} = \beta_{ea} \alpha_{ea}^{\pi^x, \pi^x} E_t \hat{\pi}_{ea,t+1}^x + \frac{1 - \alpha_{ea}^{\pi^x, \pi^x}}{\beta_{ea}} \hat{\pi}_{ea,t-1}^x + \alpha_{ea}^{\pi^x, m^x} (\widehat{mc}_{ea,t}^x - \hat{Q}_{ea,t}) - \xi_{ea,t}^{\pi^x}, \quad (14)$$

where hats on variables denote percentage deviations from the steady-state. The structure of Equation (14) is consistent with a fully micro-founded Phillips curve as derived in, for example, Casas et al. (2017) for the case without strategic complementarities in price setting and hence constant mark-ups as well as with inflation indexation.⁶ Marginal costs for exports are given by

⁶ See Appendix A for a sensitivity analysis in which we modify the Phillips curve so as to reflect the presence of strategic complementarities.

$$\begin{aligned}
\widehat{mc}_{ea,t}^{x^{dcp}} &= \alpha_{ea}^{mc^x, \hat{x}} \hat{x}_{ea,t} + \alpha_{ea}^{mc^x, \pi^{ppi}} \left\{ \alpha_{ea}^{mc^x, oil} (\widehat{Q}_{ea,t} + \hat{p}_t^{oil} - \hat{p}_{ea,t}^{ry}) \right. \\
&+ (1 - \alpha_{ea}^{mc^x, oil}) [\omega_{ea,us}^{M,int} (\widehat{Q}_{ea,t} + \hat{p}_{us,t}^{ry} - \hat{p}_{ea,t}^{ry}) \\
&+ (1 - \delta_{as}^{dcp}) \omega_{ea,as}^{M,int} (\widehat{Q}_{ea,t} - \widehat{Q}_{as,t} + \hat{p}_{as,t}^{ry} - \hat{p}_{ea,t}^{ry}) \\
&+ \delta_{as}^{dcp} \omega_{ea,as}^{M,int} (\widehat{Q}_{ea,t} + \hat{p}_{as,t}^{rx dcpus} - \hat{p}_{ea,t}^{ry}) \left. \right\} \\
&+ \gamma^{mc^x, \hat{y}} (\omega_{ea,us}^X \hat{y}_{us,t} + \omega_{ea,as}^X \hat{y}_{as,t}),
\end{aligned} \tag{15}$$

where \widehat{Q}_{it} is the bilateral real exchange rate against the US dollar, $\hat{p}_{ea,t}^{rx dcpus}$ represents export prices relative to US consumer prices defined by $p_{ea,t}^{rx dcpus} \equiv P_{ea,t}^{x^{dcp}} / P_{us,t}^{cpi}$, and $\hat{p}_{ea,t}^{ry}$ the price of output relative to consumer prices defined by $P_{ea,t}^{ry} \equiv P_{ea,t}^{ppi} / P_{ea,t}^{cpi}$. Equation (15) is similar in spirit to the micro-founded marginal cost function in Casas et al. (2017), in particular in that it incorporates the costs of imported intermediates, for which we also assume DCP.⁷ Accordingly, $\omega_{ea,j}^{M,int}$ denotes the steady-state share of the euro area's intermediate imports that are sourced in country j . In Appendix A, we explore alternative specifications of the export-price Phillips curve, including for example alternative real activity measures. Export prices are linked to export-price inflation according to

$$\hat{p}_{ea,t}^{rx dcpus} - \hat{p}_{ea,t-1}^{rx dcpus} = \hat{\pi}_{ea,t}^{x^{dcp}} - \hat{\pi}_{us,t}^{cpi}, \tag{16}$$

and the terms-of-trade are given by

$$tot_{ea,t} = \frac{P_{ea,t}^x}{P_{ea,t}^m}, \tag{17}$$

where it should be recalled that P_{it}^x and P_{it}^m are denoted in domestic currency, in contrast to $P_{it}^{x^{dcp}}$ which is denoted in US dollars.

2.3 Market clearing and net foreign asset position

The market clearing condition implies that real GDP deflated by the GDP deflator is given by

$$P_{ea,t}^{defl} \cdot y_{ea,t} = P_{ea,t}^{cpi} \cdot ci_{ea,t} + P_{ea,t}^g \cdot g_{ea,t} + P_{ea,t}^x \cdot x_{ea,t} - P_{ea,t}^m \cdot m_{ea,t}, \tag{18}$$

where g_{it} represents government expenditures with deflator P_{it}^g , ci_{it} consumption and investment, and $P_{ea,t}^{defl}$ is the weighted average of $P_{ea,t}^{ppi}$ and $P_{ea,t}^x$.

⁷ Notice that in the version of ECB-Global considered in this paper, as in Dieppe et al. (2017), we lump together private consumption and investment into a consumption and investment aggregate. Hence, except for the effect of DCP on marginal costs, in this version of ECB-Global we cannot explore differences in the implications of DCP for households' consumption and firms' investment decisions.

The aggregate net foreign asset position evolves according to

$$P_{ea,t}^{ppi} \cdot NFA_{ea,t} = I_{ea,t-1}^l \cdot P_{ea,t-1}^{ppi} \cdot NFA_{ea,t-1} + P_{ea,t}^x \cdot X_{ea,t} - P_{ea,t}^m \cdot M_{ea,t}, \quad (19)$$

where $I_{ea,t-1}^l$ is the nominal gross long-term interest rate.

2.4 Consumer prices

Finally, consumer prices are defined by

$$\begin{aligned} P_{ea,t}^{cpi} = & \bar{\omega}_{ea}^{oil} (P_t^{oil} + Q_{ea,t}) + (1 - \bar{\omega}_{ea}^{oil}) a_{ea}^H P_{ea,t}^{ry} \\ & + (1 - \bar{\omega}_{ea}^{oil}) (1 - a_{ea}^H) [\omega_{ea,us}^{M,nonoil} (P_{us,t}^{ry} + Q_{ea,t}) \\ & + \delta_{as}^{dcp} \omega_{ea,as}^{M,nonoil} (P_{as,t}^{rxdcpus} + Q_{ea,t}) \\ & + (1 - \delta_{as}^{dcp}) \omega_{ea,as}^{M,nonoil} (P_{as,t}^{ry} + Q_{ea,t} - Q_{as,t})], \end{aligned} \quad (20)$$

where $\bar{\omega}_{ea}^{oil}$ is the steady-state share of oil and a_{ea}^H the steady-state share of imported non-oil goods in the consumption basket.⁸

2.5 Parameterisation

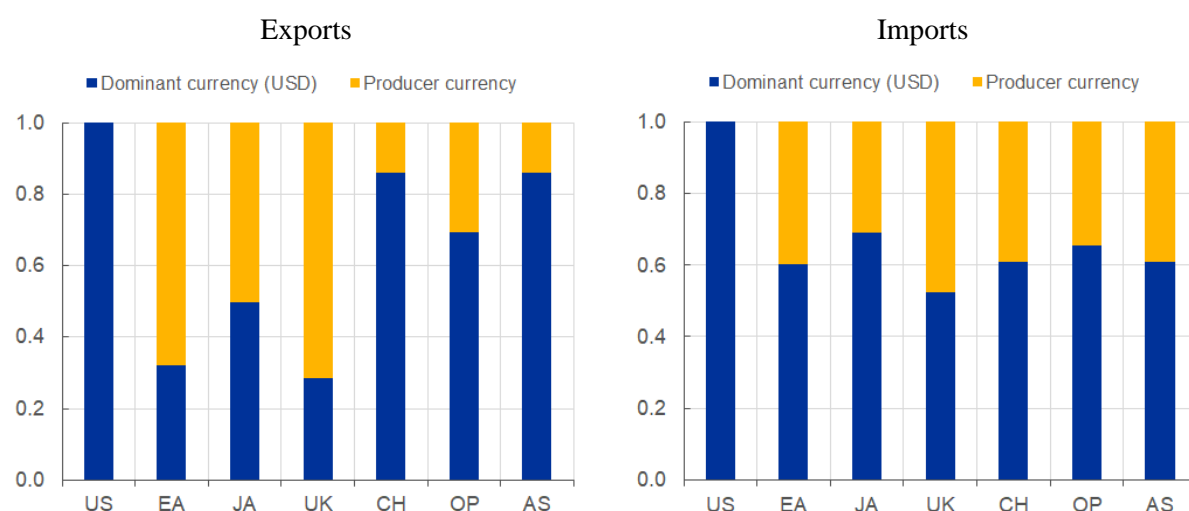
The modifications introduced in ECB-Global in the context of DCP require parameterisations, in particular the shares of economies' total imports that are priced and invoiced in US dollars vs. the producer's currency, as well as the coefficients in the export-price Phillips curve in Equation (14) and the associated marginal costs in Equation (15).

For the shares of economies' exports priced and invoiced in US dollars, we mostly rely on the data of Gopinath (2015). Due to the lack of granularity in the data, we make the following assumptions to introduce at least some heterogeneity in the bilateral invoicing patterns for a given exporter. First, we assume that economies invoice all their exports to the US in US dollars; similarly, the US invoices all its exports in US dollars. Second, we assume that economies invoice the same share of their exports in US dollars across all other destinations. The weighted average of the resulting invoicing shares corresponds to the country-level invoicing shares provided by Gopinath (2015). Moreover, in the baseline version of ECB-Global with DCP, we only allow for two invoicing currencies, namely the US dollar and the producer's currency; we allocate the share of economies' exports invoiced in currencies other than the US dollar and the producer's currency in the data of Gopinath (2015) to the

⁸ Because the current version of ECB-Global does not distinguish between consumption and investment, this price index also applies to investment.

producer's currency. Because the data of Gopinath (2015) do not distinguish between extra and intra-euro area trade, for the euro area, we use data from Eurostat.⁹ For reasons of data availability, for EM Asia, we take the export-weighted average of the data for India, Indonesia, Pakistan, South Korea, and Thailand. For China, due to lack of data, we assume the share of exports invoiced in US dollars is the same as for EM Asia. Finally, for the rest of the world, we take the export-weighted average of the invoicing share data of all countries in the model. It is worthwhile to emphasise that the parameterisation of ECB-Global we consider does not correspond to full DCP but rather to partial DCP, i.e., a mixture of DCP and PCP, as in general only a share of an economy's exports and imports smaller than unity is assumed to be invoiced and priced in US dollars.

Figure 2: Distribution of invoicing currencies in ECB-Global



Note: The left-hand side panel displays the values for the shares of economy i 's exports invoiced in domestic currency and US dollar, respectively. The right-hand side panel displays the values of the shares of economy i 's imports invoiced in US dollars and the producers' currencies, respectively. In order to ensure consistency of trade invoicing patterns the latter are obtained by combining the shares of exports of economy i 's trading partners that are invoiced in US dollars with the shares of economy i 's imports accounted for by individual trading partners. The data are taken from Gopinath (2015) and Eurostat for the euro area, which refer to extra-EU exports. The values for exports in US dollar for China are assumed to be identical to those for EM Asia.

The left-hand side panel in Figure 2 displays the resulting distribution of invoicing shares of exports in US dollar and the producer's currency based on the data of Gopinath (2015) and Eurostat as well as the assumptions discussed above. The right-hand side panel depicts the distribution of import currency invoicing shares that are implied by imposing global consistency, based on the data on export invoicing currency shares of Gopinath (2015) and Eurostat, the assumptions discussed above, countries' total nominal imports and exports in the data, as well as bilateral import shares in the data and used in ECB-Global for $\omega_{ij}^{M,nonoil}$. Abstracting from the US, where both exports and imports are

⁹ Eurostat provides data on trade shares by invoicing currency of euro area extra-EU trade, which we assume to be equal to extra-euro area trade due to lack of more adequate data.

fully invoiced in US dollars by assumption, Figure 2 suggests that, in line with Figure 1, the share of exports invoiced in US dollars is more heterogeneous across countries than the share of imports invoiced in US dollars implied by the currency invoicing shares of exports and the bilateral trade shares. More specifically, while invoicing of exports in US dollars ranges between 29% for the UK to around 85% for EM Asia, the share of imports invoiced in US dollars ranges between 52% for the UK and 69% for Japan.

As regards the parameterisation of the export-price Phillips curve and the associated marginal costs in Equations (14) and (15), for reasons of simplicity we assume the parameterisation to be symmetric to the domestic output-price Phillips curve and marginal cost equation in ECB-Global (see Dieppe et al.; 2017). In Appendix A, we explore the sensitivity to alternative parameterisations of key coefficients.

3 Implications of DCP in ECB-Global

In order to illustrate the implications of DCP in ECB-Global, we discuss the impulse responses to domestic monetary policy shocks in EM Asia, the US, and the euro area. We carry out sensitivity analyses in Appendix A, where we document that the dynamic properties of DCP in ECB-Global are very similar if we account for strategic complementarities and alternative specifications of the export-price Phillips curve and the marginal cost equation. Finally, it is worthwhile repeating that the parameterisation of ECB-Global we consider does not correspond to full DCP but rather to partial DCP, i.e., a mixture of DCP and PCP, as in general only a share of an economy's exports and imports smaller than unity is assumed to be invoiced and priced in US dollars.

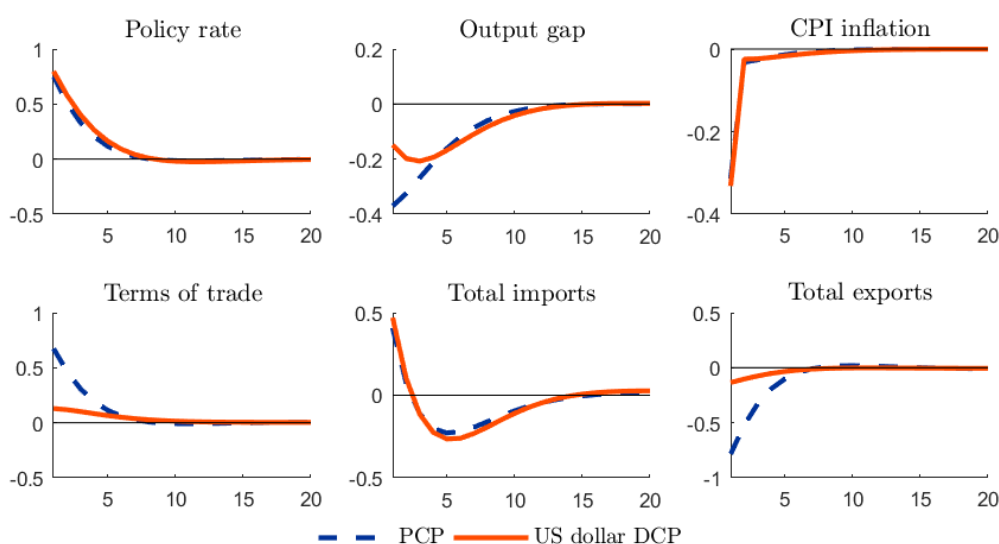
3.1 Emerging Asia

As explained in more detail in Dieppe et al. (2017), in ECB-Global, a contractionary monetary policy shock transmits through several channels. First, in response to a contractionary monetary policy shock of 25 basis points in EM Asia, the policy rate rises persistently (see Figure 3, which shows the response of the annualised policy rate). The rise in the policy rate transmits to a rise in private sector borrowing rates, which compresses private consumption and investment. Moreover, bank-lending terms tighten in response to the worsening of the outlook, which further contracts private consumption and investment. The rise in the discount rate and the worsening of the outlook depresses equity prices, which further contracts private consumption. Government expenditures are countercyclical and increase, thereby off-setting the contractionary effects of the monetary policy tightening somewhat. In

contrast, the rise in government debt induced by the fiscal response raises the sovereign risk premium, which feeds back to a rise of the private sector borrowing rate, even though this effect is quantitatively marginal. Given the uncovered interest parity condition, the exchange rate of EM Asia's currency appreciates, which under PCP induces expenditure-switching away from domestically produced goods towards imports; the dynamics of trade and the implications of PCP and DCP are discussed in much more detail below. Against the background of the decline in the output gap that arises through the aforementioned channels, domestic and CPI inflation falls (see Figure 3 which shows the response of annualised CPI inflation), which induces the central bank to loosen monetary policy.

The differences between PCP and DCP primarily manifest in differences in the response of the trade variables (Figure 3). Specifically, consistent with the findings in Casas et al. (2017), EM Asia exports fall much less under DCP than under PCP in response to a contractionary domestic monetary policy shock. The reason for this is that a significant share of EM Asia's exports are invoiced and sticky in US dollars and are thereby immune to the multilateral appreciation of its currency triggered by the contraction in domestic monetary policy. In contrast, EM Asia's imports respond almost identically under PCP and DCP. This is because it is essentially irrelevant for imports whether these are subject to DCP or PCP, as EM Asia's currency appreciates multilaterally against all currencies in response to the contraction in domestic monetary policy. Consequently, and in line with the findings in Casas et al. (2017), under DCP expenditure-switching in the economy in which the monetary policy contraction materialises occurs mostly through imports, rather than through both imports and exports.

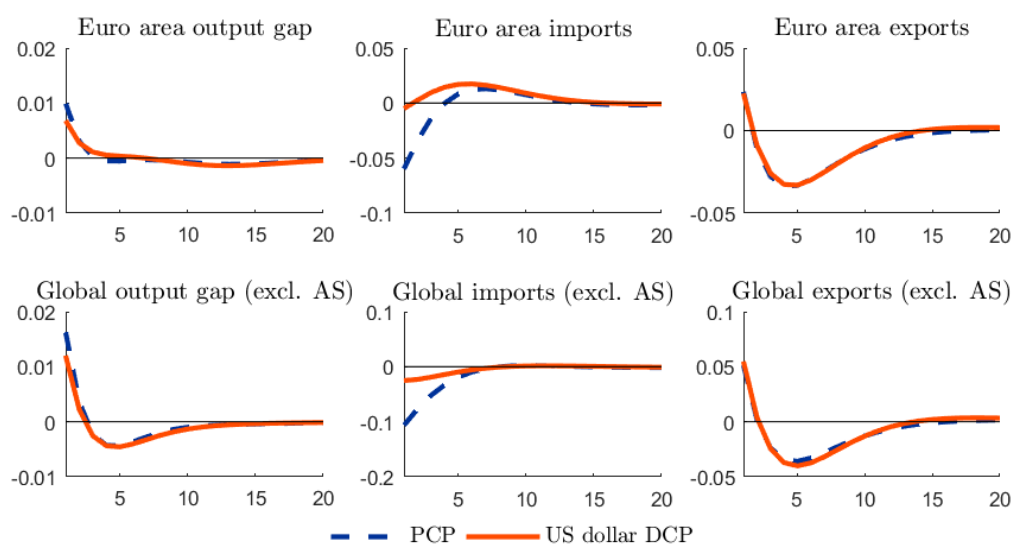
Figure 3: Domestic effects of an EM Asia monetary policy shock



The differences in the response of exports across DCP and PCP translate — taking into account the share of exports in GDP — into differences in the response of the output gap. Specifically, consistent with the findings in Casas et al. (2017), as exports drop by less, EM Asia’s output gap also falls less in response to a contractionary domestic monetary policy shock under DCP as compared to PCP. Finally, and again consistent with the findings in Casas et al. (2017), EM Asia’s terms-of-trade are much more stable under DCP than under PCP in response to a domestic monetary policy shock.

In ECB-Global, spillovers from a monetary policy shock in EM Asia to the rest of the world arise primarily through trade. In terms of magnitude, the spillovers to the rest of the world are small, and differences across PCP and DCP mainly relate to the responses of imports (Figure 4). Specifically, euro area imports — from all destinations — do not fall under DCP, in contrast to the case of PCP. The reason for this is that under DCP, while EM Asia’s currency appreciates against the Euro, this hardly reduces euro area demand for imports from EM Asia, as most of the latter are invoiced and sticky in US dollars, against which the euro is stable. Consequently, under DCP expenditure-switching in the euro area in response to a contractionary monetary policy shock in EM Asia occurs primarily through exports but not through imports. Overall, as EM Asia accounts only for a rather small share of the euro area’s total exports this effect is eventually barely visible in the euro area output gap. The results for the global economy as whole (excluding EM Asia) are very similar to those for the euro area.

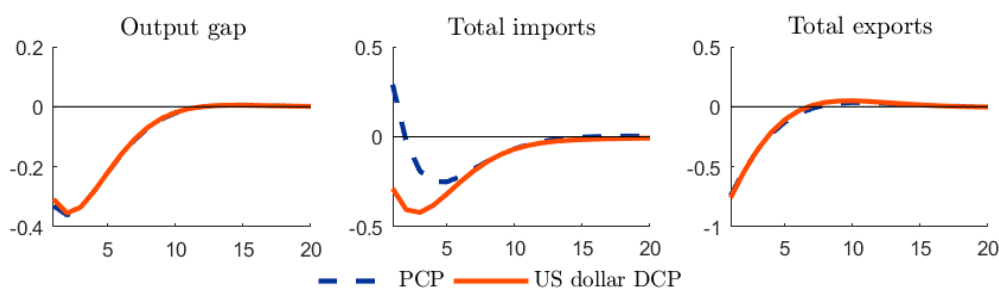
Figure 4: Spillover effects of an EM Asia monetary policy shock



3.2 United States

The domestic transmission of a contractionary monetary policy shock in the US is very similar — except for trade — to that in EM Asia.¹⁰ Domestic responses to a contractionary US monetary policy shock are almost identical under PCP and DCP (Figure 5). The sole difference in the responses across DCP and PCP relates to imports, which fall more strongly under DCP. Specifically, in contrast to PCP, under DCP the appreciation of the US dollar against all other currencies in response to the tightening in US monetary policy does not entail a fall in import prices in US dollar terms, which mutes expenditure-switching from domestically produced goods to imports. This amplifies the contraction in imports that results from the slowdown in domestic real activity. Overall, because net exports account only for a small share of US GDP, this difference hardly affects the output gap response.

Figure 5: Domestic effects of a US monetary policy shock



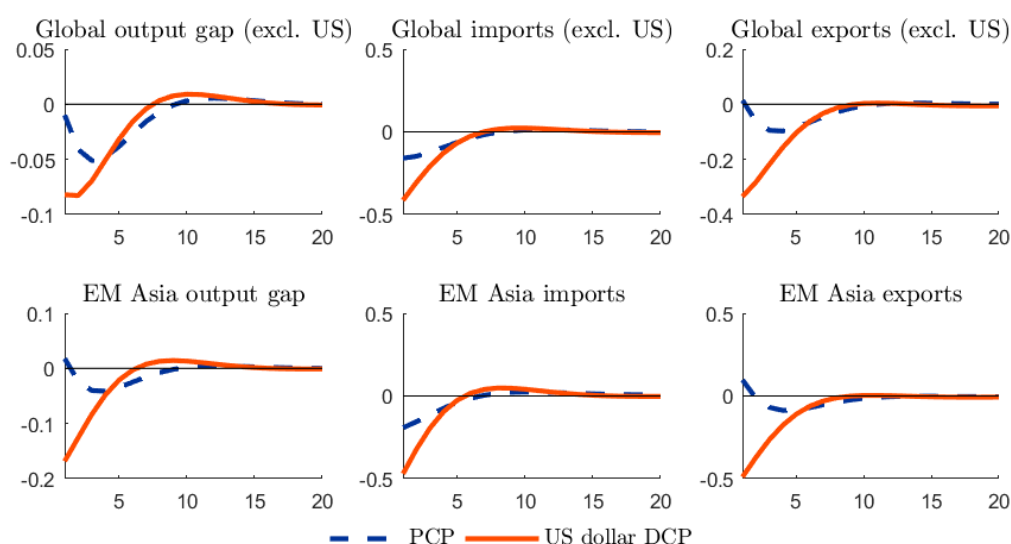
Spillovers from a contractionary US monetary policy shock arise through real and financial channels (for details see Dieppe et al.; 2017). Specifically, in ECB-Global, the tightening in bank-lending terms spills over to other economies, dampening private consumption and investment. Similarly, the rise in US sovereign risk premia spills over to other economies, even though it is again very small quantitatively. And finally, the drop in US equity prices also drags down global equity prices. As the financial spillover channels are identical under PCP and DCP, the differences between the effects of a US monetary policy shock across the pricing paradigms are solely due to US dollar pricing of exports.

The differences in the implications of a contractionary US monetary policy shock across PCP and DCP for spillovers to the global economy are sizeable for trade and real activity (Figure 6). Consistent with the findings in Boz et al. (2017), the tightening in US monetary policy elicits a much stronger slowdown in global trade under DCP than under PCP. In fact, both global imports and exports drop

¹⁰ To ensure comparability, the size and persistence of the US monetary policy shock is comparable to that for EM Asia in the previous section (see Figure 3).

more than twice as much under DCP than under PCP, which, in turn, translates into a sharper drop of global real activity. The reason for this is that under DCP a large share of international trade is invoiced and sticky in US dollars, even if it does not involve the US. As a result, imports become more expensive in local-currency terms in response to the multilateral appreciation of the US dollar for all economies. The spillovers from the tightening in US monetary policy to real activity are amplified under DCP in the short term in particular in case of EM Asia, the country block which has the largest share of exports invoiced in US dollars.

Figure 6: Spillover effects of a US monetary policy shock



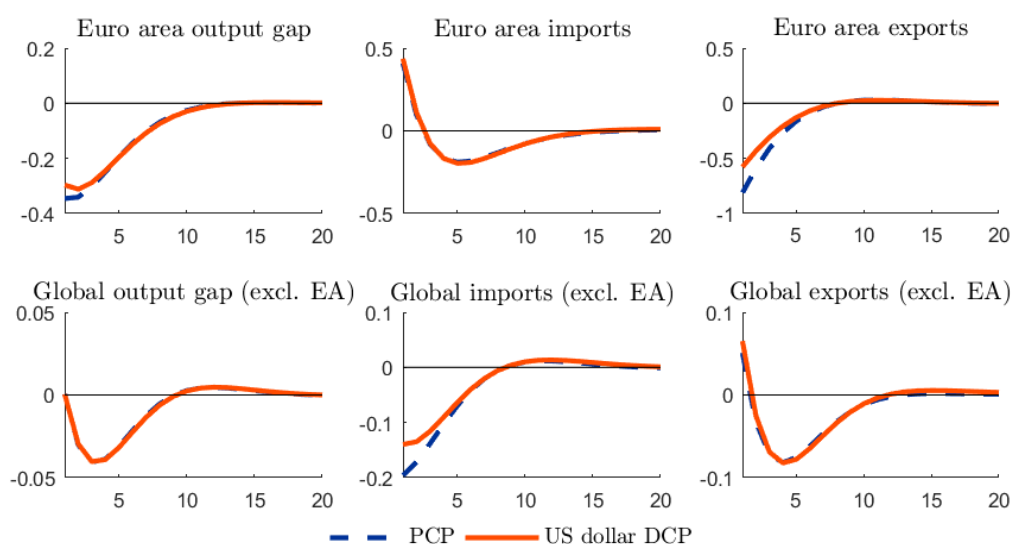
3.3 Euro area

The responses to a contractionary euro area monetary policy shock are very similar under DCP and PCP (Figure 7).¹¹ The only difference arises in the case of exports, which fall — consistent with the findings in Casas et al. (2017) and with the case for EM Asia — by somewhat less under DCP than under PCP. The reason for this is again that a part of the euro area’s exports are invoiced and sticky in US dollars under DCP, insulating them from the multilateral appreciation of the euro. However, in contrast to the case of EM Asia, for the euro area the differences in the responses of imports and exports across DCP and PCP are smaller, as the share of euro area exports invoiced in US dollars is much lower than for EM Asia. As a result, the responses of domestic real activity and any other variable are altered less under DCP than in the case of EM Asia and the differences across PCP and DCP are small for the euro area. Similarly, there are no noticeable differences across DCP and PCP at

¹¹ To ensure comparability, the size and persistence of the euro area monetary policy shock is comparable to that for EM Asia and the US in the previous sections (see Figure 3).

the global level, except for imports, which are less sensitive to a monetary policy contraction in the euro area; this is again because a part of the rest of the world's imports from the euro area are invoiced in US dollars under DCP instead of euros under PCP, insulating them from the multilateral appreciation of the euro triggered by the monetary policy tightening.

Figure 7: Domestic and spillover effects of a euro area monetary policy shock



4 The implications of the Euro becoming a second dominant currency

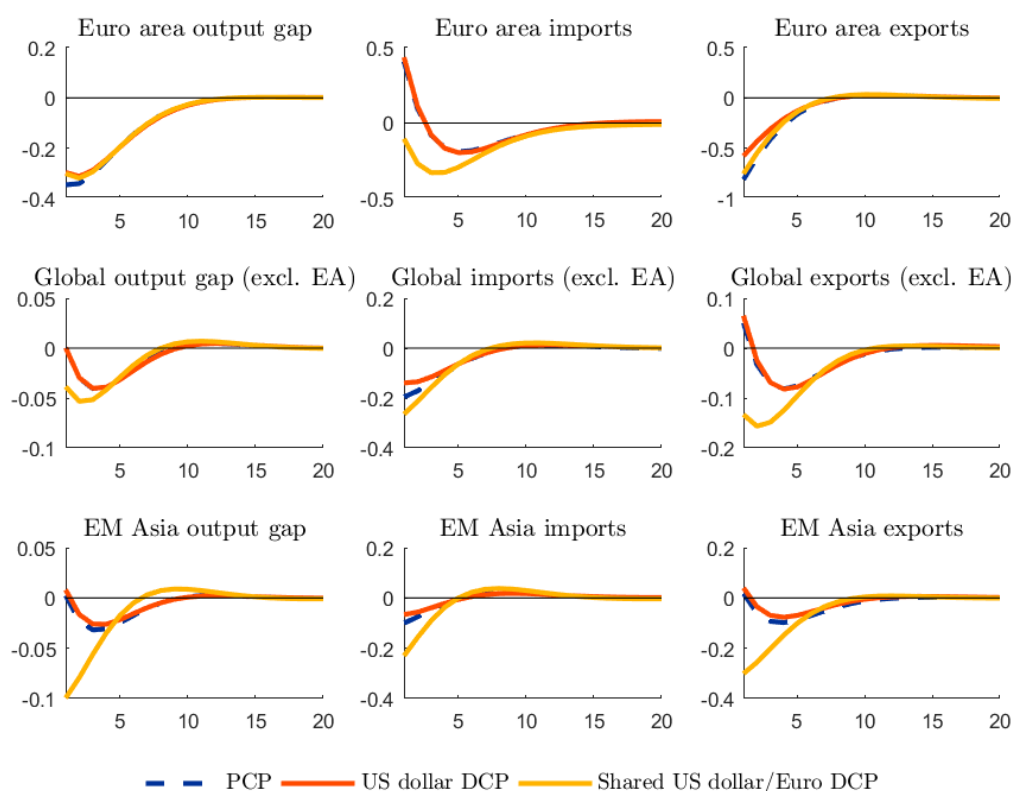
In order to illustrate the usefulness of ECB-Global in particular in the context of DCP for policy analysis, we simulate a shared DCP scenario in which the euro rivals the US dollar as a second dominant currency in global trade. To that end, we distribute the data-based US dollar invoicing shares displayed in Figure 2 symmetrically to the US dollar and the euro for all countries. For example, we assume that in EM Asia where in the baseline US dollar DCP scenario around 85% of exports are invoiced in US dollars, in the shared DCP scenario 42.5% of exports are invoiced in US dollars and 42.5% in euros. As in the baseline US dollar DCP scenario, the remaining exports continue to be invoiced in the producer's currency in the shared DCP scenario. We also continue to assume that countries invoice all their exports in US dollar when trading with the US; correspondingly, we now assume that countries invoice all their exports in euros when trading with the euro area. Moreover, we continue to assume that all countries invoice the same share of their exports in US dollars and euros, respectively, across all other destinations. Finally, we assume that trade between the US and the euro area is invoiced in US dollars. Figure 8 and Figure 9 below display

the implications of this invoicing configuration of shared DCP in comparison with PCP and the baseline US dollar DCP scenario discussed in Section 3.¹²

4.1 Euro area

In the euro area, imports fall somewhat more strongly under shared DCP. Since the euro is a dominant currency in the shared DCP scenario, and trade of the euro area with all countries but the US is invoiced in euros, its multilateral appreciation in response to the interest rate increase implies that import prices for the euro area in domestic currency are more stable than under PCP or US dollar DCP. As a result, expenditure-switching from domestically produced goods to imports is weakened and the fall in imports triggered by the slowdown in real domestic activity is amplified. Moreover, the effects on domestic real activity in the euro area are marginally weaker under the shared DCP scenario than under PCP, but are very similar compared to US dollar DCP.

Figure 8: Domestic and spillover effects of a euro area monetary policy shock



¹² The size and persistence of the US and euro area monetary policy shocks are identical to those in the previous sections (see Section 3).

As the importance of the euro as a currency in international trade rises, spillovers from the euro area to the rest of the world increase. Specifically, a contractionary euro area monetary policy shock induces a slowdown of global trade under the shared DCP scenario; both global imports and exports fall more strongly than under PCP or US dollar DCP. The reason is that under shared DCP, a part of international trade is invoiced in euros. As a result, imports become more expensive in local-currency terms in response to the multilateral appreciation of the euro for all economies but the US. The implications are again particularly important for trade and real activity in EM Asia, since that country block invoices the largest share of exports in euros as per our assumptions.

4.2 United States

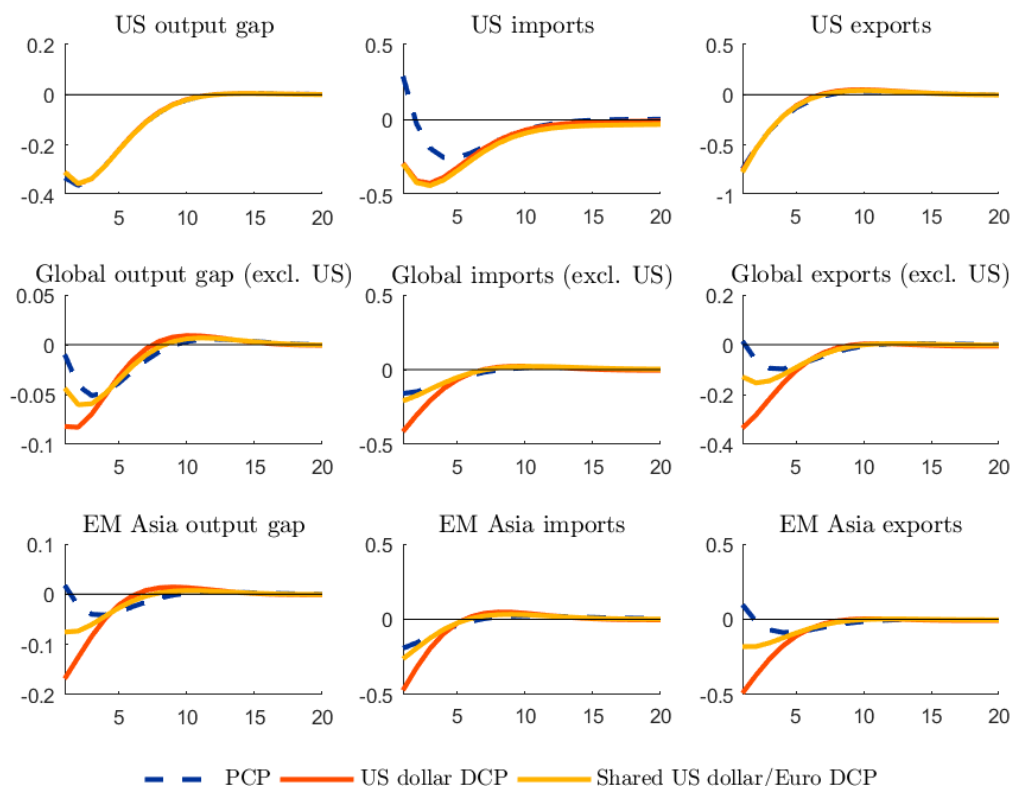
The implications of a contractionary US monetary policy shock in the shared DCP scenario are in line with those from the baseline US dollar DCP scenario described in Section 3.2. Since all trade involving the US, including trade between the US and the euro area, continues to be invoiced in US dollars under shared DCP, there are no differences in the domestic response of US variables compared to US dollar DCP. The main difference between US dollar DCP and shared DCP is that spillovers to the rest of the world are smaller under the latter. This is because under shared DCP, the US dollar and the euro take an equally dominant role as currencies in international trade, and the share of global exports invoiced in US dollars is therefore lower. As a result, the transmission of shocks from the US to the rest of the world through the exchange rate is weakened.

5 Conclusion

This paper introduces DCP into ECB-Global, the ECB's main macroeconomic model for the global economy used for scenario analyses. Consistent with the findings in the literature that considers fully structural models, in ECB-Global, DCP has important implications for the transmission of shocks in economies which invoice a large share of exports and imports in US dollars, relating in particular to the role of expenditure-switching and the US dollar exchange rate. First, in case of domestic shocks that appreciate the domestic currency multilaterally, expenditure-switching occurs primarily through imports; exports, being invoiced and sticky in US dollars, are insulated from the multilateral appreciation of the domestic currency. The differences in the response of exports across DCP and PCP translate into differences in the response of the output gap. Second, under DCP, global trade becomes less sensitive to domestic shocks, but more sensitive to US shocks. In fact, under DCP, US monetary policy is a major driver of global trade, even for transactions that do not involve the US as trading

partner. Third, in a world where the euro rivals the US dollar as a second dominant currency in international trade, US shocks become less important for the global economy while international spillovers from the euro area increase.

Figure 9: Domestic and spillover effects of a US monetary policy shock



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A Additional appendix

It is interesting to explore the sensitivity of the findings regarding the effects of DCP on the dynamics of domestic and trade variables in ECB-Global. In particular, we compare the dynamics implied by the baseline version of DCP laid out in Section 2 with those implied by several alternative specifications. In order to save space, we only present the impulse responses for the monetary policy shocks in EM Asia and the US; the results for the other shocks discussed in Section 3 are available upon request.

A.1 Accounting for strategic complementarities

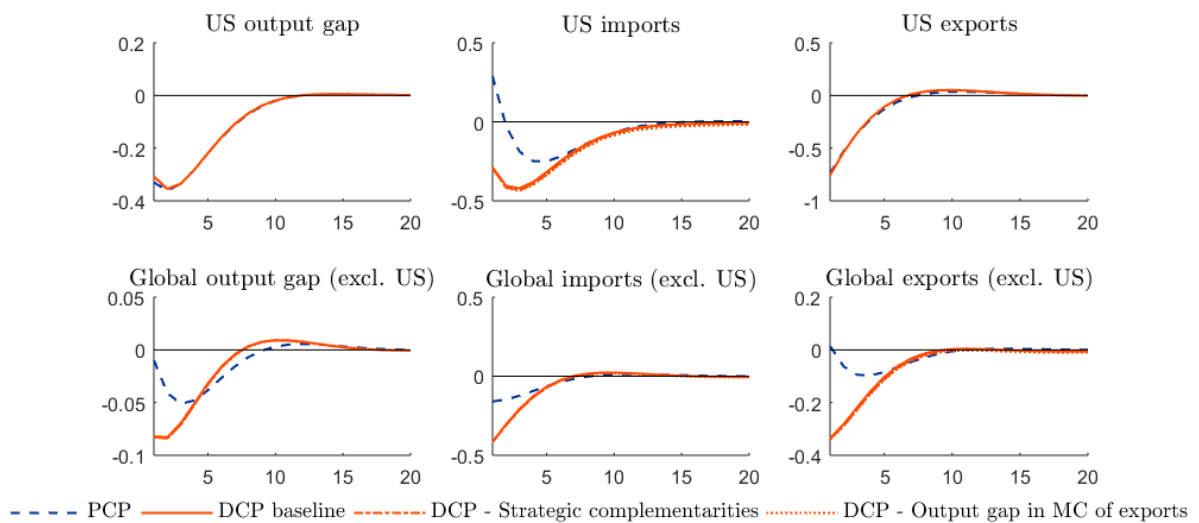
Casas et al. (2017) discuss the role of strategic complementarities and variable mark-ups for the ability of their model with DCP to fit key moments in the data. We therefore examine the sensitivity of the baseline version of ECB-Global with DCP to additionally introducing strategic complementarities. Specifically, we introduce the difference between the export-weighted average of all destination markets' domestic output price and the producer's export price on the right-hand side of the export-price Phillips curve

$$\begin{aligned} \hat{\pi}_{ea,t}^{x dcp} = & \beta_{ea} \alpha_{ea}^{\pi^x, \pi^x} E_t \hat{\pi}_{ea,t+1}^x + \frac{1 - \alpha_{ea}^{\pi^x, \pi^x}}{\beta_{ea}} \hat{\pi}_{ea,t-1}^x \\ & + \alpha_{ea}^{\pi^x, mc^x} \left[\frac{1}{1 + \Gamma} \cdot (\widehat{mc}_{ea,t}^x - \widehat{Q}_{ea,t}) \right. \\ & \left. + \Gamma \sum_j \omega_{ea,j}^{x nonoil} (\hat{p}_{j,t}^{ry} - \widehat{Q}_{j,t}) - \hat{p}_{ea,t}^{rx dcpus} \right] - \xi_{ea,t}^{\pi^x} \end{aligned} \quad (A1)$$

The parameter Γ governs the strength of strategic complementarities. In particular, for $\Gamma = 0$ we obtain the Phillips-curve from the baseline in Equation (14); for $\Gamma \rightarrow \infty$ the producer's marginal costs become immaterial for the pricing decision, and only the prices of local competitors in export markets matter. In line with Casas et al. (2017), we set $\Gamma = 1$. Figures 10 and 11 document that this change in the specification of the export-price Phillips curve for the domestic and cross-border transmission of EM Asia and US monetary policy shocks barely alters the dynamics compared to the baseline version of ECB-Global with DCP.

Figure 10: Sensitivity analysis on EM Asia monetary policy shock — Introducing strategic complementarities and alternative specification of export-price Phillips curve

Figure 11: Sensitivity analysis on US monetary policy shock — Introducing strategic complementarities and alternative specification of export-price Phillips curve



A.2 Alternative specification of marginal costs

Next we replace exports in the marginal costs in Equation (15) by a linear combination of the producer's exports and output gap. The intuition for this alternative specification is that there is competition for factors of production between firms that export and firms that produce for the domestic market only. Hence, exporting firms' marginal costs may not only increase when foreign demand rises, but also when domestic demand rises and thereby puts upward pressure on wages. Figures 10 and 11 also document that this change in the specification of the export-price Phillips curve again barely alters the dynamics compared to the baseline version of ECB-Global with DCP.

A.3 Alternative parameterisation of export-price Phillips curve and marginal costs

Finally, we consider alternative parameterisations of the key coefficients in the newly introduced equations of ECB-Global under DCP. Specifically, we consider alternative values for the coefficient on marginal costs in the export-price Phillips curve in Equation (14) — namely 0.001, 0.004 (baseline), and 0.01 — and alternative values for the coefficient on exports in the export marginal costs equation in Equation (15) — namely 1, 2.5 (baseline), and 4. Figures 12 and 13 and Figures 14 and 15, respectively, show that the dynamics in ECB-Global under DCP are hardly altered by perturbing these parameters within reasonable bounds.

Figure 12: Sensitivity analysis on EM Asia monetary policy shock — Alternative parameterisation of marginal costs equation

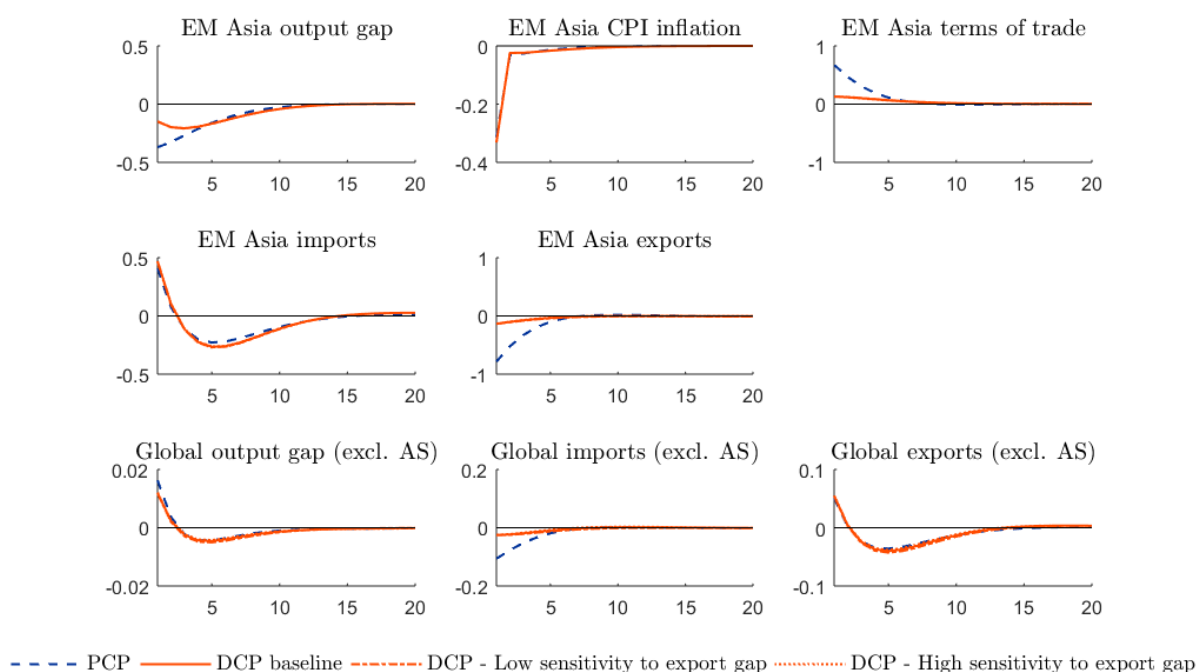


Figure 13: Sensitivity analysis on US monetary policy shock — Alternative parameterisation of marginal costs equation

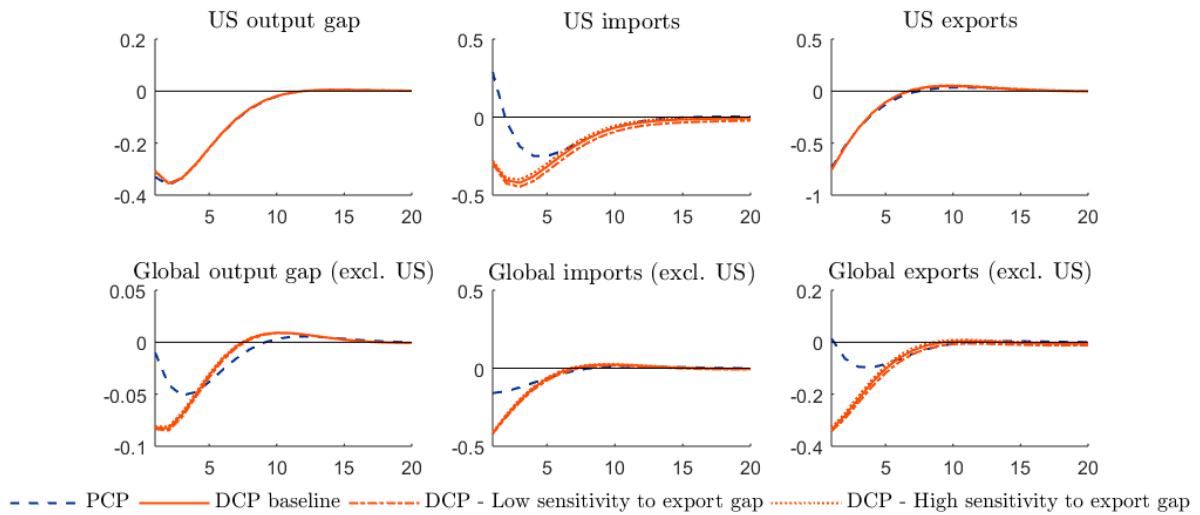


Figure 14: Sensitivity analysis on EM Asia monetary policy shock — Alternative parameterisation of export-price Phillips curve

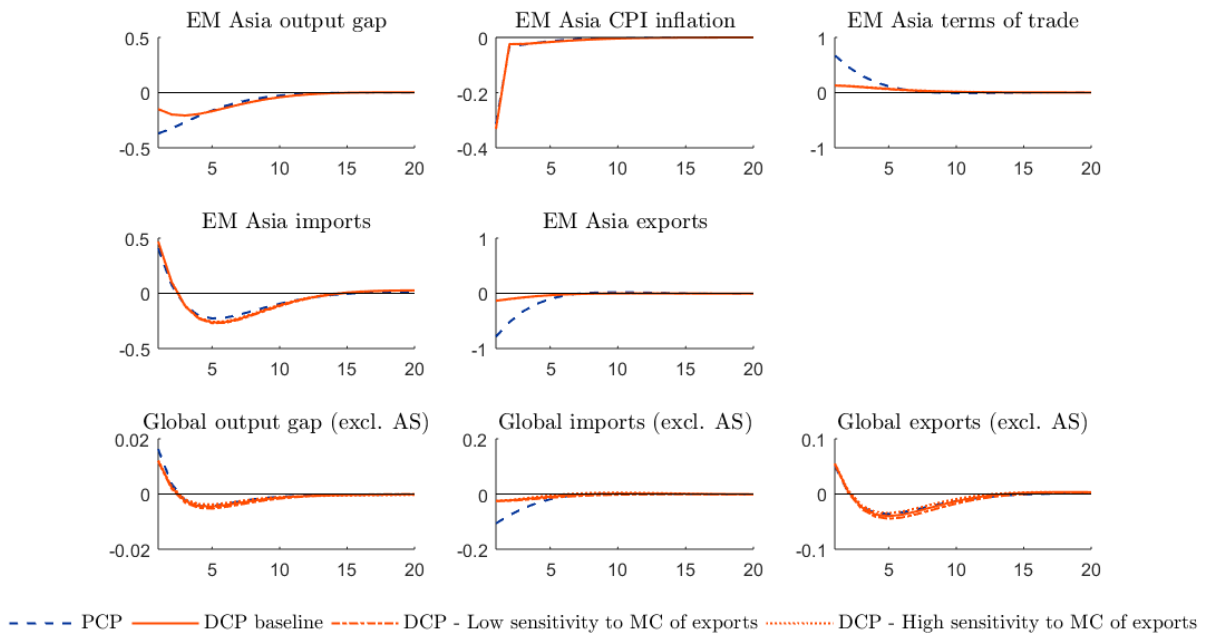
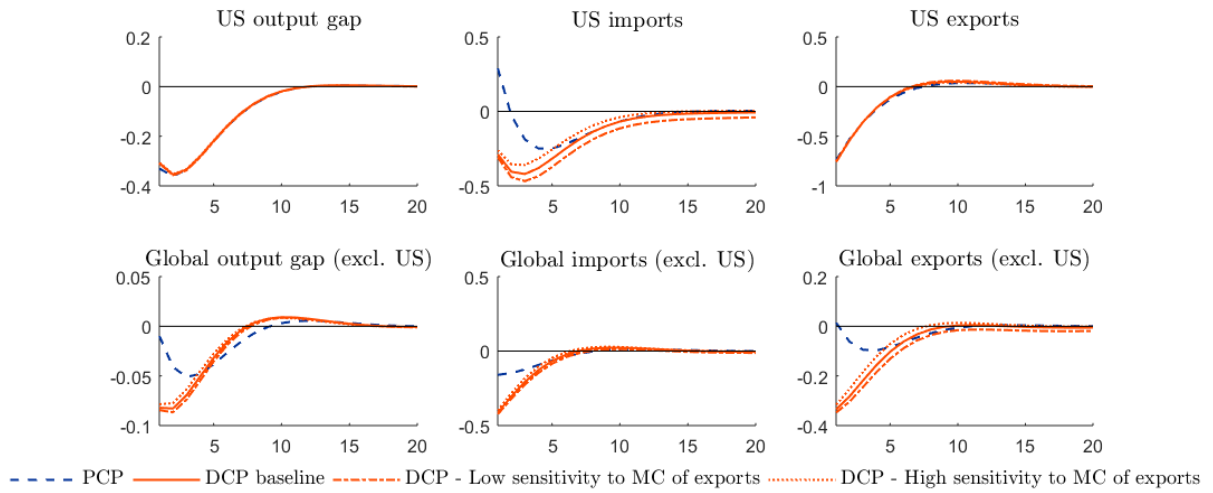


Figure 15: Sensitivity analysis on US monetary policy shock — Alternative parameterisation of export-price Phillips curve



Data availability statement

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

Acknowledgements

We would like to thank Allan Dizioli, Martino Ricci, Ben Schumann, Björn van Roye, Ine Van Robays, two anonymous referees, and seminar participants at the ECB for helpful comments and suggestions. The views expressed in the paper are those of the authors and do not necessarily reflect those of the BIS, the ECB or the Eurosystem and should not be reported as such.

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PDF

ISBN 978-92-899-3890-7

ISSN 1725-2806

doi:10.2866/879528

QB-AR-19-102-EN-N