Working Paper Research

July 2020 N° 386

Low pass-through and high spillovers in NOEM : What does help and what does not

by Gregory de Walque, Thomas Lejeune, Ansgar Rannenberg and Raf Wouters

NationalBank OF BELGIUM
Eurosystem

Editor

Pierre Wunsch, Governor of the National Bank of Belgium

Statement of purpose:

The purpose of these working papers is to promote the circulation of research results (Research Series) and analytical studies (Documents Series) made within the National Bank of Belgium or presented by external economists in seminars, conferences and conventions organised by the Bank. The aim is therefore to provide a platform for discussion. The opinions expressed are strictly those of the authors and do not necessarily reflect the views of the National Bank of Belgium.

The Working Papers are available on the website of the Bank: http://www.nbb.be

ISSN: 1375-680X (print)
ISSN: 1784-2476 (online)

Abstract

This paper jointly analyses two major challenges of the canonical NOEM model: i) combining a relatively important exchange rate pass-through at the border with low pass-through at the consumer level, and ii) generating significant endogenous international business cycle synchronization. These issues have been separately analysed in the literature, with extension of the NOEM with a distribution sector for mitigating the exchange-rate pass-through, and foreign input trade for spillovers. We show that introducing input trade for price-maker firms rehabilitate the model regarding the pass-through disconnect, which is especially helpful to model very open economies, while adding a distribution sector lacks flexibility to do so. Moreover, these two extensions of the canonical model mitigate the expenditure switching effect, with implications in terms of international synchronization.

JEL classification: E31, E32, F41, F44.

Key words: Exchange rate pass-through, International trade in intermediate goods, International correlations, Small open economies.

Authors:
Gregory de Walque, Economics and research department, NBB
– e-mail: gregory.dewalque@nbb.be.
Thomas Lejeune, Economics and research department, NBB and HEC-University of Liège
– e-mail: thomas.lejeune@nbb.be
Ansgar Rannenberg, Economics and research department, NBB
– e-mail: ansgar.rannenberg@nbb.be
Raf Wouters, Economics and research department, NBB
– e-mail: rafael.wouters@nbb.be

We would like to thank the participants to the various seminars and conferences where the paper has been presented. Comments and remarks by Luca Dedola, Cédric Duprez, Jesper Linde, Tommaso Monacelli, Eva Ortega, Chiara Osbat, Massimiliano Pisani and Spyridon Sichlimiris are greatfully acknowledged.

TABLE OF CONTENTS

1 Introduction

New open economy macroeconomic models are well known to face two major challenges. First, they have a clear difficulty to combine a relatively important exchange rate pass-through at the border with low pass-through at the consumer level (a puzzle labelled hereafter the ERPT disconnect). Second, they struggle to replicate endogenously the empirically observed international synchronization of real and nominal variables, as emphasized by Justiniano and Preston (2010) among others. The literature has tackled either the first or the second of these puzzles, but as far as we know, there has been no clear attempt to link both issues. The low pass-through problem has been mainly addressed by augmenting the standard model with a domestic distribution sector (herafter DIST) according to the intuition of Burstein, Neves and Rebelo (2003) and Corsetti and Dedola (2005). Foreign intermediate inputs in production (FIIP, hereafter) appear to be a promising avenue for enhancing endogenous cross-border spillovers via the trade channel (e.g Huang and Liu (2007), Burstein, Kurtz and Tesar (2008) or Johnson (2014).[1]

Noteworthy, this repartition of the tasks by macromodellers, i.e. DIST to address the low pass-through and FIIP for endogenous spillovers, is at odds with the conclusion of the careful econometric analysis of Campa and Golberg (2010) that "*the dominant channel for CPI sensitivity is through the cost arising from imported input used in goods production*". With this in mind, one can legitimately wonder whether introducing FIIP in the New Keynesian open macroeconomic set-up would not be the stone allowing to hit the two above mentioned birds.[2] The statement by Campa and Goldberg (2010) is also quite orthogonal to the canonical NOEM implicit assumption flagged by Gali and Monacelli (2005) that the transmission of exchange rate to consumption prices is heavily influenced by the degree of trade openness. This reveals an important discrepancy between the empirical evidence and the common practice in open macro-modelling, which we would like to address in this paper.

Specifically, we assess the ability of FIIP and DIST to match three stylized facts. First, the transmission of exchange rates to border import prices is strong and rapid while the transmission to consumption prices is much lower and delayed (see for example Burstein and Gopinath, 2014, or Colavecchio and Rubene, 2020). Second, a rapid empirical check of the responsiveness of

[1] Throughout the paper, we remain in the pure tradition of trade models, even though we acknowledge that financial linkages might be of first importance to explain cross-border spillovers, as put forward by e.g. Dedola and Lombardo (2013), Kamber and Toenissen (2013) and Kollman (2013).

[2] Note that the idea that FIIP matters for both nominal and real dynamics appears in filigrane in the contributions of Shi and Xu (2007 and 2010), Huang and Liu (2007) and Eyquem and Kamber (2014).

consumption prices to import prices leads to the conclusion that, for industrialized countries, this sensitivity is weakly, if at all, affected by trade openness. Third, according to variables of the OECD Trade in Value Added (TiVA) database, trade openness and the import content of exports (excluding transit) are strongly positively correlated. The last two observations bring forward new interesting questions investigated in the paper. Could FIIP be one important element behind the explanation of the weak influence of trade openness in the relationship between consumption prices with respect to import prices? How could FIIP mitigate it?

The present contribution ambitions to re-assess the respective merits of the DIST and FIIP mechanisms for the above-mentioned puzzles. Treating low pass-through and international real synchronization together implies to rely on a general equilibrium analysis. As pointed out by Corsetti, Dedola and Leduc (2008),[3] compared with the ERPT empirical literature dealing either with partial equilibrium reasoning (as Campa and Goldberg, 2010) or with VAR analysis (e.g. Shambaugh, 2008), New Keynesian dynamic general equilibrium macro models allow to distinguish the structural, shock-invariant, ERPT from the shock-dependent sensitivity of prices to exchange rate movements. We add that the general equilibrium effects depend very much on the structure of the demand for imports which, according to Obstfeld and Rogoff (1995), weights the respective strengths of the aggregate demand externality, on the one hand, and the terms-of-trade externality, on the other hand. Throughout the paper, we assess first how the DIST and FIIP variants of the NOEM affect both the structural ERPT and the structural demand for imports, and we then show their implications regarding the ability of the model to generate both low tranmissions of exchange rate to final prices and large international spillovers through general equilibrium effects.

Here is a summary of the main results we obtained. First we show analytically that, in partial equilibrium, both DIST and FIIP mitigate the effects of the volatility of the exchange rate on consumption prices even though they operate through different channels. DIST achieves this outcome by reducing the volatility of the border price of imports, in contradiction with the ERPT disconnect evidence. In contrast with DIST, FIIP reduces the weight of import prices in the CPI. This result is crucial in order to replicate the empirical evidence on the ERPT disconnect and on the absence of a significant link between the ERPT to consumer price and trade openness. We show that FIIP allows a plausible modelling of very open economies while DIST, in itself, does not.

Jumping then to general equilibrium effects, we document that both DIST and FIIP have

[3]and restated more recently by Burlon, Notarpietro and Pisani (2018) and Ortega and Osbat (2020).

the potential to strongly attenuate the expenditure switching effect. This reduces the volatility of the demand for domestic production factors, and therefore the domestic producers' prices, an element which is essential for obtaining the low transmission of the exchange rate to final prices, over and above the partial equilibrium effects. Noteworthy, as far as FIIP is concerned, the potential to reduce the expenditure switching effect (and to obtain a low volatility of producers' prices) is inversely related with the substitutability between domestic and imported intermediate inputs in the production function. This general equilibrium outcome contrasts with the conventional wisdom conveyed by the partial equilibrium reasoning of Campa and Goldberg (2010) who state that "*Calibrated price effects of exchange rates and import prices are smaller when economies can more flexibly substitute away from imported components into domestic components when producers are confronted with an adverse cost shock*".

Finally, we examine the impact of DIST and FIIP on the the ability of the model to generate positive cross-country correlation of inflation and economic activity in the presence of selected demand and supply shocks. Depending on the type of shock, the implied reaction of the central bank and its effect on the uncovered parity condition, the terms-of-trade externality may oppose or enhance the aggregate demand effect. For shocks implying that the policy interest rate moves procyclically, the expenditure switching effect tends to encourage the cross-border transmission of shocks to real activity. The opposite is true for shocks for which the interest rate moves contracyclically. By reducing the expenditure switching effect, DIST and FIIP (entering production as complements) increase cross-country GDP spillovers for shocks which move activity and the interest rate in opposite directions, while the inverse is true for shocks triggering a procyclical interest rate response. Noteworthy, FIIP switches the demand of imports away from an private demand motivation towards a production/exports incentive. This feature usefully links the within country imports and exports. However, as the private demand of the Home country reacts in general more to Home specific shocks than the Foreign demand for Home goods, FIIP is somewhat less efficient than DIST in eliciting large aggregate demand effects and endogenous real spillovers. Finally, across all the shocks we consider, FIIP is more successful at inducing endogenous inflation spillovers as it opens a cross-country link between the Home producers' price and the Foreign cost of production, and vice versa.

The paper is structured as follows. Section 3 extends the canonical (two-country) NOEM model with both DIST and FIIP mechanisms. This allows to highlight their respective structural consequences through an analysis that covers (i) the composition of the consumption price index (Section 4), (ii) its implication for the structural exchange rate pass-through down the pricing chain (Section 5) and (iii) their consequences on the composition of the demand for imported goods and the expenditure switching effect (Section 6). The careful study of these structural equations brings a better understanding of the dynamic analysis led in Section 7 through the simulation of an unexpected exchange rate shock. This dynamic general equilibrium exercise underlines the way the DIST and FIIP mechanisms alter the interactions between the real and nominal sides of the economy. Section 8 describes for four different country specific shocks[4] how the two mechanisms under scrutiny alter the ability of the model to generate endogenous business cycles synchronicity.

2 Some stylized facts about ERPT disconnect and trade openness

In their third empirical finding, Burstein and Gopinath (2014) state that border prices are more sensitive than consumer prices to variations in the exchange rate, a conclusion already reached by Campa and Goldberg (2010). For 21 OECD countries on the period 1975-2003, they report elasticities of the border prices with respect to one-year ahead exchange rate fluctuations that are more often statistically different from zero than from unity, while it is the other way round for the consumption prices elasticities (cf. their Table 7, first two columns). According to their estimations, the average of the per country ratio between the consumer prices elasticity and the border prices elasticity is equal to 0.14. This means that, on average, after one year, for the sample and period considered, consumption prices are about 6 times less reactive to exchange rate changes than border prices. Using the Jorda (2005) local projection method, Colavecchio and Rubene (2020) come to quite the same outcome for the 19 members of the euro area during the period 1997-2019, with more precise estimates. For the euro area as a whole, consumption prices are, after one year, about 8 times less reactive to exchange rates than border prices.[5] These authors bring also more information about the timing of the transmission of exchange rate to prices by estimating the sensitivity on impact, after one year and after two years. For the EA-12, the ratio of the price sensitivities to exchange rates roughly doubles between one and two years. These pieces of information can be synthesized in a first stylized fact:

[4] We consider a monetary policy shock, a productivity shock, a Smets-Wouters (2007) risk-premium shock to the difference between the interest rate faced by the households and this fixed by the central bank, and a consumer preference shock.

[5] On the grounds of an unweighted country average, the relative sensitivity of consumer prices with respect to border prices falls to about one fifth.

Stylized fact 1: *The transmission of exchange rate movements to border prices is large and rapid, though imperfect. The transmission of exchange rate fluctuations to consumer prices is much smaller and more gradual.*

Let us label this exchange rate transmission, which is high at the border and low at the consumer prices level, as the exchange rate path-through (ERPT herafter) disconnect. As discussed above, a first measure of disconnectedness is obtained from the ratio of the exchange rate elasticity of consumer prices to the one of border prices, after one year.[6] Interestingly, using the elasticities computed by the two above mentioned studies, the intensity of the per country ERPT disconnect appears to be only weakly related to the degree of trade openness. This result is obtained by regressing our measure of ERPT disconnect on import to value added ratio across countries. Note that the latter is not computed from the national accounts concept. Instead, we use the OECD TiVA[7] database which allows one to remove transit goods from the imports series.[8] The obtained import to value added ratio is then averaged over the period 1995-2015.[9] The corresponding scatterplots and OLS regression lines are displayed on Figure 1 below, respectively for the Campa and Goldberg (2010)[10] and the Colavecchio and Rubene (2020) ratios of exchange rate elasticities after one year. In both cases the predictive power of the regression is extremely low and the slope coefficient is not significantly different from zero.

On the premise that exchange rate fluctuations mostly affect consumption prices via their impact on border prices, this result states that the sensitivity of consumption prices to import prices is only weakly related with the degree of trade openness. We may easily verify this intuition

[6] Obviously, the smaller the ratio, the stronger the disconnect.

[7] Acronym for Trade in Value Added.

[8] The correction is especially important for very small and very open economies, some of them endowed with large sea hubs. As an example, the import to value-added series drops from 70% to 51% in Belgium and from 59% to 37% for the Netherlands (averages for the 1995-2015 period).

[9] This period is admitedly not consistent with the one covered by the Campa and Goldberg (2010) study. Unfortunately, the TiVA database does not provide information for the years before 1995. However, one may argue that, even though the specific country values for the import to value added would certainly be different (lower), the countries ordering would probably remain quite unchanged.

[10] For the OLS regression based on the elasticities estimated by Campa and Goldberg (2010, first two columns of Table 7) we did not considered the two outliers that are Ireland and Austria, even though they appear in the scatter plot. The extreme values taken by the ratio of elasticities (resp. 1.33 and -0.9) for these two countries is explained by the low and insignificantly different from zero elasticity of the border prices with respect to the exchange rate.

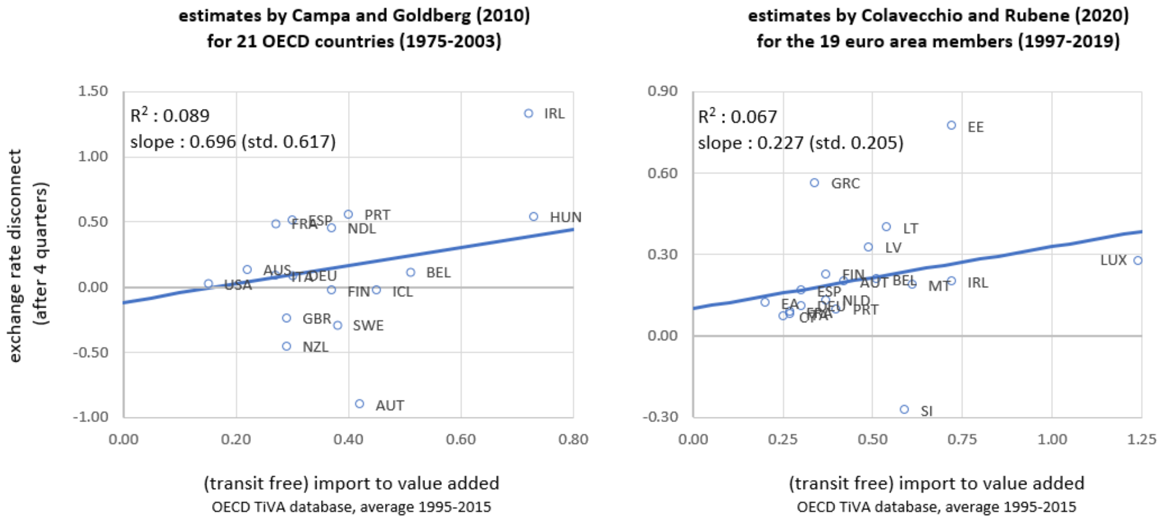

Figure 1: Weakness of the link between trade openness and the ERPT disconnect (measured as the relative exchange rate elasticities of consumer and border prices)

by regressing, per country, the consumption price inflation π_t^c on the import price inflation π_t^f and other potentially important drivers, as the oil price inflation in national currency π_t^{oil} (a proxy for the price of energy) and the log-difference of the value added deflator π_t^{VA} (a proxy for the domestic producers prices):

$$\pi_t^c = \beta_0 + \beta_1 \pi_t^f + \beta_2 \pi_t^{oil} + \beta_3 \pi_t^{VA} + \varepsilon_t \quad . \tag{1}$$

The country-specific OLS coefficients β_1 estimate the sensitivity of consumption price inflation to international prices and can be scattered against trade openness as measured by the import to value added ratio. Quarterly prices data are taken from the OECD Economic Outlook database for the period 1995Q2-2019Q2. The outcome presented on Figure 2 (left panel) below leads to the same conclusion as Figure 1. The blue dots and blue regression line correspond to the country specific coefficients β_1 estimated with the above displayed OLS equation, while the grey dots and grey OLS line are obtained when the restriction $\beta_2 = \beta_3 = 0$ is imposed. Even though none of the estimated slopes of the blue and grey regression lines are significantly different from zero, the consumption price sensitivity to import price is generally biased upwards when the two control variables are not included in the regressors. The empirical evidence gathered in Figures 1 and 2 can be summarized in the next stylized fact:

Stylized fact 2: *The sensitivity of consumer prices to border prices is weakly, if at all, related with the degree of trade openness.*

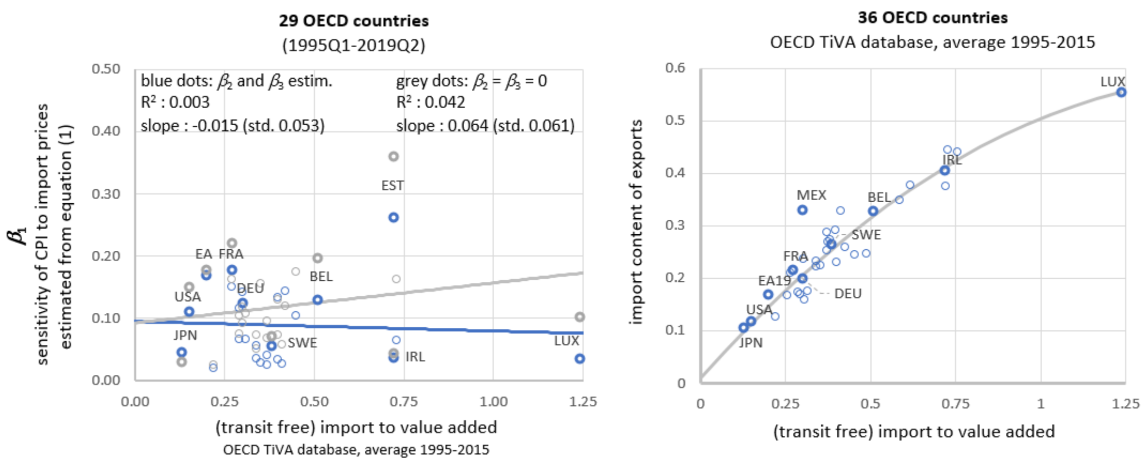

Figure 2: Relationship with trade openness: weak for the elasticity of CPI to border prices and strong for the import content of exports

Note that the canonical NOEM model states exactly the opposite, namely that the weight of import prices in the CPI is given by the import to absorption ratio which is directly related to trade openness (see Gali and Monacelli, 2005). Campa and Goldberg (2010) open the list of the potential drivers for the sensitivity of consumption prices with respect to international prices with distribution margins and international trade in intermediate inputs. They insist that these two elements may play an important role in mitigating the transmission of exchange rate fluctuations to consumer prices. The OECD TiVA database gives an indication of the share of intermediate inputs in international trade by reporting, among others, the import content of exports. This variable is scattered against the import to value added ratio on Figure 2 (right panel) for the 36 OECD countries for which data are available. Noteworthy, the obtained cloud of dots is accurately fitted by a quadratic convex equation which indicates that a larger trade openness coincides with a deeper integration in the global production process. This is our third stylized fact:

Stylized fact 3: *Trade openness and import content of exports are strongly correlated.*

In the next section, we extend the canonical NOEM model to take into account the presence of distribution margins and the role of intermediate imported inputs. First, this enables us to check analytically whether the correlation found in Stylized fact 3 may indeed help explain the lack of relation highlighted in Stylized fact 2. Second, it clarifies further the way distribution margins affect the structural relationship between consumption and import prices.

3 Households' preference and production structure

Households allocate consumption (C_t) and investment (I_t) between homogeneous final goods produced domestically and imported from abroad according to the usual CES preference:

$$\zeta_t = \left[\phi_H^{\frac{1}{\lambda_H}} \zeta_{h,t}^{D\,\frac{\lambda_H - 1}{\lambda_H}} + (1 - \phi_H)^{\frac{1}{\lambda_H}} \zeta_{f,t}^{D\,\frac{\lambda_H - 1}{\lambda_H}} \right]^{\frac{\lambda_H}{\lambda_H - 1}} \quad , \quad \zeta \in \{C, I\} \,. \tag{2}$$

In the spirit of Burstein et al. (2003), traded goods require transportation, storage, retailing and other local value added services in order to reach the final users. The "D" superscript refers to the "distributed" status of the traded goods available to the households. Parameter ϕ_H represents the steady-state share of domestically produced-and-distributed goods in domestic absorption, and λ_H is the households' Armington elasticity of substitution between domestic and imported distributed goods. For simplicity, and following Burstein et al. (2003), we assume a Leontief distribution technology to produce retail goods, where δ domestic goods are required to bring one unit of homogenous good to retail stores,[11] such that

$$\zeta_{j,t}^D = \min \left\{ (1+\delta)\, Y_{j,t} ; \frac{1+\delta}{\delta} Y_{h,t}^d \right\} \quad \text{with } j \in \{h, f\} \quad .$$

Variable $Y_{h,t}$ (resp. $Y_{f,t}$) represents Home (resp. Foreign) produced homogenous goods and the "d" superscript stands for the homogenous goods used for distribution purposes. The corresponding price index[12] is

$$P_t = \left[\phi_H P_{h,t}^{D\,1-\lambda_H} + (1 - \phi_H)\, P_{f,t}^{D\,1-\lambda_H} \right]^{\frac{1}{1-\lambda_H}} \quad . \tag{3}$$

$P_{h,t}^D$ and $P_{f,t}^D$ are the retail prices for Home and Foreign goods respectively, i.e. the prices paid by the households after inclusion of the distribution margin. Given the assumed complementarity between final goods and distribution services, these retail prices can be decomposed as

$$P_{j,t}^D = \frac{1}{1+\delta} P_{j,t} + \frac{\delta}{1+\delta} P_{h,t}, \quad \text{with } j \in \{f, h\} \quad , \tag{4}$$

with $P_{h,t}$ and $P_{f,t}$ being respectively the domestic producers' price and the border price of foreign imported goods.

Home homogenous goods ($Y_{h,t}$) that satisfy domestic and foreign demands are produced by firms acting on a perfectly competitive market. These firms buy intermediate inputs on a market

[11] We simplify somehow the structure of Corsetti and Dedola (2005) who distinguish tradable and non-tradable goods. This refinement is not necessary for the point we intend to make here.

[12] For simplicity we assume that investment and consumption bundles share the same home bias and trade elasticity. This implies that their price is alike and in the rest of the paper we will mostly refer to it as the consumption price index.

in monopolistic competition and combine them using a Dixit-Stiglitz aggregator. Domestic intermediate inputs, indexed by i on the unit circle, are obtained from the combination of domestic value added (Y_t) with Foreign homogenous final goods ($Y_{f,t}$) through a CES technology. Let us refer to the latter element as the foreign intermediate inputs in production (FIIP). The domestic value added is produced with a Cobb-Douglas technology from the services of capital and labour rented from domestic households. On the grounds of the usual assumption in the New Keynesian literature that the labour and capital production factors are not firm specific but are rented by the price-setting intermediate firms on the same market, all the domestic intermediate firms share the same marginal cost

$$\begin{aligned} MC_{h,t}(i) &= \left[\phi_P MC_{y,t}^{1-\lambda_p} + (1-\phi_P) P_{f,t}^{1-\lambda_p}\right]^{\frac{1}{1-\lambda_p}} \quad , \text{ for } i \in [0,1] \qquad (5) \\ \text{with } MC_{y,t} &= \frac{w_{h,t}^{1-\alpha}\left(r_{h,t}^k\right)^{\alpha}}{\alpha^{\alpha}(1-\alpha)^{1-\alpha} e^{\varepsilon_{h,t}^a}} \end{aligned}$$

where $r_{h,t}^k$ is the rental rate of capital, $w_{h,t}$, the price of labor, α, the Cobb-Douglas capital share and $\varepsilon_{h,t}^a$, an AR(1) total factor productivity exogenous process. The weight of Foreign inputs in the CES technology is represented by $(1-\phi_P)$, while λ_p is the firms' elasticity of substitution between Home and Foreign inputs. The Foreign production structure is exactly symmetric to the Home one.

According to this, imports by the Home economy can be divided between the households' demand for Foreign goods that compose the consumption and investment bundles - let's denote them respectively $C_{f,t}$and $I_{f,t}$ - on the one hand, and the firms' demand to produce the domestic final good, $Y_{f,t}$, on the other hand:

$$\begin{aligned} M_t &= C_{f,t} + I_{f,t} + Y_{f,t} \quad , \qquad (6) \\ \text{where } \zeta_{f,t} &= \frac{1-\phi_H}{1+\delta}\left(\frac{P_{f,t}^D}{P_t}\right)^{-\lambda_H} \zeta_t, \text{ with } \zeta \in \{C, I\} \qquad (7) \\ \text{and } Y_{f,t} &= (1-\phi_P)\left(\frac{P_{f,t}}{MC_{h,t}}\right)^{-\lambda_p} Y_{h,t} \quad . \qquad (8) \end{aligned}$$

The first factor on the right-hand-side of equation (7) expresses that the structural share of imports in the distributed Foreign goods decreases with the required distribution services.

4 Foreign final and intermediate goods in domestic absorption

In the generalized set-up developed supra, domestic private demand incorporates two different types of imports: Foreign final goods that directly enter consumption and investment bundles on the one hand, and Foreign goods used as inputs to produce the domestic share of private demand on the other hand. Therefore, the overall steady-state import content of private demand,

$$\phi_c^m \equiv \frac{\bar{c}_f + \bar{\imath}_f}{\bar{c} + \bar{\imath}} + \left(1 - \frac{\bar{c}_f + \bar{\imath}_f}{\bar{c} + \bar{\imath}}\right) \frac{\bar{y}_f}{\bar{y}_h},$$

is determined by

$$\phi_c^m = \phi_c^{m,d} + \left(1 - \phi_c^{m,d}\right) \rho_m \ , \tag{9}$$

$$\text{with } \phi_c^{m,d} \equiv \frac{\bar{\zeta}_f}{\bar{\zeta}} = \frac{1 - \phi_H}{1 + \delta} \left(\frac{\overline{p}_f^D}{\overline{p}}\right)^{-\lambda_H} \ , \tag{10}$$

$$\text{and } \rho_m \equiv \frac{\bar{y}_f}{\bar{y}_h} = (1 - \phi_P) \left(\frac{\overline{p}_f}{\overline{mc}_h}\right)^{-\lambda_P} \ . \tag{11}$$

From now on, ρ_m symbolizes the steady-state share of Foreign inputs into domestic homogeneous good, while $\phi_c^{m,d}$ represents the share of foreign goods that households directly buy as identified imports, or loosely speaking, the direct import content of absorption. In the canonical NOEM where $\delta = 0$ and $\phi_P = 1$, the import content of absorption ϕ_c^m boils down to its first component. Imports for the sole direct absorption purpose implies $\bar{m} = (\bar{c}_f + \bar{\imath}_f)$, such that $\phi_c^{m,d}$ is equivalent to the import-to-absorption ratio, a natural index of trade openness. Under the assumption that the law of one price holds in steady-state (i.e. $\bar{p}_h = \bar{p}_f$), one easily obtains that all the relative prices are equal to unity and parameter ϕ_H, which is referred to as the home bias in households' preference, is equivalent to the complement of the steady-state import-to-absorption ratio, as remarked by Gali and Monacelli (2005).[13] From the moment DIST and FIIP are taken into account, concepts need to be clarified a bit further. Parameter ϕ_H corresponds then to a *preference bias for distributed final domestically produced goods, which include themselves some foreign value added.* Even though parameter ϕ_H is still inversely connected to trade openness, this relationship is now mitigated by the need for distribution services, δ, and the firms' technological home bias, ϕ_P.

4.1 Distinction between trade openness and import content of absorption

By substituting equations (7) and (8) into (6) at steady-state, it appears that, in the NOEM model enriched with FIIP, the equivalence between trade openness and import content of consumption collapses, which is not the case for the DIST mechanism.

[13] Note that the assumption that the law of one price holds in steady state is absolutely not required for the purpose of our analysis. Whatever the steady state value of $\bar{p}_f^D/\bar{p}$, the negative linear relationship between home bias in preference and the import-to-absorption ratio remains valid.

Lemma 1: *Assuming (i) balanced trade at steady-state and (ii) that only the production of goods and services for private demand and exports requires foreign inputs, FIIP implies that the steady-state equivalence between trade openness, the share of foreign goods directly chosen by households and the import content of absorption is broken down:*

$$\phi_c^{m,d} = \frac{\bar{m}}{\bar{c}+\bar{\imath}} - \frac{\rho_m}{1-\rho_m} \tag{12}$$

$$\text{and } \phi_c^{m} = (1-\rho_m)\frac{\bar{m}}{\bar{c}+\bar{\imath}} \quad . \tag{13}$$

Proof. From equations (6), (7) and (8), real imports can be expressed as

$$M_t = \frac{1-\phi_H}{1+\delta}\left(\frac{P_{f,t}^D}{P_t}\right)^{-\lambda_H}(C_t+I_t) + (1-\phi_P)\left(\frac{P_{f,t}}{MC_{h,t}}\right)^{-\lambda_P} Y_{h,t} \quad . \tag{14}$$

Under assumption *(ii)*,[14] the demand for the domestically produced homogeneous goods (private domestic demand, distribution services and exports) is given by

$$Y_{h,t} = \frac{\phi_H+\delta}{1+\delta}\left(\frac{P_{h,t}^D}{P_t}\right)^{-\lambda_H}(C_t+I_t) + X_t \quad . \tag{15}$$

Assuming balanced trade and substituting for (15) into (14), one obtains in steady-state

$$\bar{m} = (\bar{c}+\bar{\imath})\left(\frac{1-\phi_H}{1+\delta}\left(\frac{\bar{p}_f^D}{\bar{p}}\right)^{-\lambda_H} + \frac{(1-\phi_P)\left(\overline{p}_f/\overline{mc}_h\right)^{-\lambda_P}}{1-(1-\phi_P)\left(\overline{p}_f/\overline{mc}_h\right)^{-\lambda_P}}\right) \quad .$$

Equations (10) and (11) help to transform the latter expression in (12). Finally, equation (13) is obtained by substituting (12) into (9). ■

Isolating for ϕ_H, equation (12) combined with (10) establishes that the inverted relationship between trade openness and the home bias in preference is (linearly) emphasized by the importance of the distribution sector: larger distribution requirements for retail goods imply that households' preference must be (linearly) less biased towards domestically produced final goods in order to match an observed import-to-absorption ratio. The reverse holds for the import content of production: the more domestic firms incorporate foreign intermediate inputs in the production process, the less households' preference need to be oriented towards imported goods in order to cope with an observed trade openness. The preference home bias ϕ_H is not only increasing in the import content of production ρ_m, it is also convex. Convexity arises from the fact that domestic production satisfies Foreign demand on top of the domestic one, such that a

[14] This amounts to say that governement consumption is produced from domestic value added only, i.e. that for this particular type of good, ϕ_H and ϕ_P are equal to one.

share of the FIIP is re-exported after transformation. This decouples the import content of absorption from the import-to-absorption ratio, with the import content of absorption decreasing linearly in the relative importance of FIIP (cf. equation (13)).

4.2 Composition of the consumption price index

The way imported goods enter the composition of the private demand has direct consequences for the structure of the consumption price index. Indeed, goods that are clearly identified in Home retail stores as from Foreign origin are valued at the price $P_{f,t}^{D}$, while those embodied in domestically produced goods are paid $P_{h,t}^{D}$. Therefore, the share of the import price in the consumption price index directly depends of the importance of FIIP. This is highlighted in the following Proposition.

Proposition 1 *The consumption price index (3) may be re-written in linearized form as*

$$\hat{p}_t = \phi_c^{m,d} \cdot \hat{p}_{f,t} + \left(1 - \phi_c^{m,d}\right) \cdot \hat{p}_{h,t} \tag{16}$$

For $\frac{\bar{m}}{\bar{c}+\bar{\imath}}$ *and* $\delta \in \mathbb{R}_+$, $\rho_m \in [0,1]$, *equation (12) states that* $\phi_c^{m,d}$, *the share of foreign goods that enter directly into the consumption basket at the import price value, is (i) increasing linearly in trade openness* $\bar{m}/\left(\bar{c}+\bar{\imath}\right)$, *(ii) invariant in the size of the distribution sector* δ *and (iii) decreasing and concave in the intermediate foreign inputs* ρ_m *required for the domestic production process.*

Equation (16) makes obvious that, the smaller $\phi_c^{m,d}$, the lower the influence of foreign prices and the exchange rate on the consumption price index. Proposition 1 establishes formally the intuitions stated earlier about the consequences of the modifications brought to the canonical model. First of all, item *(i)* confirms that the weight of the import price in the consumption price index is directly related with trade openness. Item *(ii)* states that this weight is not influenced at all by the size of the distribution sector. As raised earlier, any variation in δ has to be compensated through the home bias in preference for the domestic distributed goods, ϕ_H, in order to cope with the observed trade openness. Keeping openness unchanged, an increase in FIIP substitutes out for the imported goods that are directly bought by the households as a share of their private demand bundle (cf. item *(iii)*). Even though a share of those new FIIP enters the private demand bundle as components of the domestically produced goods, another part is diverted through exports. This diversion effect explains why the import content of consumption decreases as FIIP increases (cf. equation (13)), as well as the non-linear relationship between the direct import content of consumption $\phi_c^{m,d}$ and intermediate foreign inputs (cf. item *(iii)*).

Proposition 1 stresses that the DIST channel influences the consumption price exchange rate pass-through only via its direct role on the import price pass-through (cf. item *(ii)*)[15] while FIIP modifies the respective weights of the import and domestic producers prices (cf. item *(iii)*). In order to catch the full implications of both types of mechanisms on the exchange rate pass-through towards consumption price, it is necessary to develop the Phillips curves of foreign exporters and domestic producers, which is the goal of Section 5 below. Before this, let us assess how the NOEM model augmented with foreign intermediate inputs complies with the stylized facts established in Section 2 above.

4.3 How does the (augmented) NOEM copes with the stylized facts

As already pointed above, Stylized fact 2 strongly calls against the implication of the canonical NOEM that the weight of import prices in the consumption price index, $\phi_c^{m,d}$, is equal to the import to absorption ratio. Let us illustrate this by drawing two scatter plots of the weight of the import price in the CPI, i.e. $\phi_c^{m,d}$, against the import to absorption ratio for the OECD countries.[16] The first one, represented by the blue dots of Figure 3, corresponds to the canonical Gali and Monacelli (2005) NOEM, with $\phi_c^{m,d} = \phi_c^m = \frac{\bar{m}}{\bar{c}+\bar{\imath}}$.[17] By construction, the blue dots are aligned on the 45° line. For countries like Ireland, the CPI would then be virtually equivalent to the import prices, which is not credible. The canonical model and its DIST variant imply an implausibly high weight for import prices in the CPI for all developed economies but the least open ones, that are Japan and the United States. Hence the canonical open economy framework is unable to properly model the nominal side of those economies for which openess actually matters. Even for less wide open economies, like the euro area for example, the difficulty to reconcile the volatilities of import and consumer prices with such weighting parameters makes

[15] Note that this is also true of all the modelling devices that affect the exchange rate pass-through to international prices, as for example the habit persistence at the level of individual goods of Jacob and Uusküla (2019).

[16] Luxembourg, the usual outlier in terms of trade openness, is excluded from the figure in order to improve readibility. For each country, the (transit free) import to absorption ratio is proxied by the (transit free) import to value added ratio (averaged over the period 1995-205) over the absorption to GDP ratio (averaged over the same period).

[17] As remarked earlier, it is also valid for the Corsetti and Dedola (2005) framework including distribution margins.

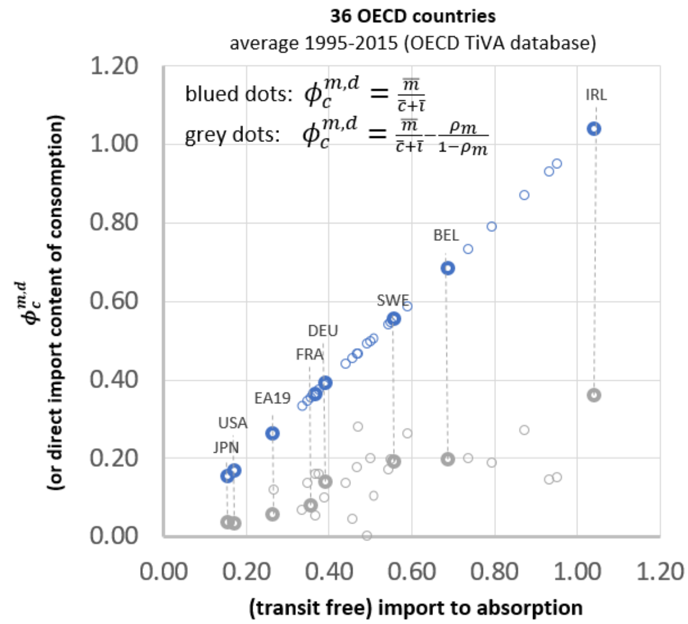

Figure 3: Observed import content of exports and implied import price weights in CPI

it complicated to use observed import prices in the estimation of the most popular estimated open economy DSGE models (cf. Adolfson et al., 2008, for example).

The second - grey dotted - scatter plot on Figure 3 is built under the assumption that domestically produced final goods are identical whatever their affectation: consumption, investment or exports. On this premise, the import content of (transit free) exports, a variable available in the OECD TiVA database, becomes a proxy for the import content of production, ρ_m. With these numbers at hand it is possible to compute for each OECD country the respective weight of the import price in the CPI as $\phi_c^{m,d} = \frac{\bar{m}}{\bar{c}+\bar{\imath}} - \frac{\rho_m}{1-\rho_m}$. This second scatter plot illustrates that, taking seriously FIIP into account, allows to sharply mitigate the strong implication of the canonical model in terms of consumption price exchange rate pass-through. The model delivers a CPI composition which becomes much more reasonable for the very open economies. Furthermore, even for the least open ones that are Japan, the USA or the euro area, it strongly reduces the transmission of exchange rates and import prices fluctuations to consumption prices. As emphasized by Wang (2010), it should also increase the exchange rate volatility in a dynamic stochastic set-up, and help replicate the high exchange rate volatility relative to that of GDP documented in the data and referred to as the exchange rate disconnect in the literature.

This exercise emphasizes that the strong cross-country correlation between FIIP and trade openness (i.e. Stylized fact 3) offers a very convincing way to reconcile the NOEM with the weak link documented between trade openness and the consumer prices sensitivity to border prices (i.e. Stylized fact 2). Note that, from a more general perspective, the globalization of the production process has implied, for most economies, an increase in both trade openness and trade in intermediate inputs.[18] The reasoning held in the previous section infers that the two forces have played in opposite direction in terms of the direct transmission of import prices to consumption prices, which might have left it relatively unchanged through time.

This section insisted mostly on the "direct" share of import prices in the CPI, which is more than proportionnaly reduced by FIIP. However, equation (13) states that the total import content of consumption decreases only linearily as imports also enter indirectly domestic production. Therefore, in order to cope with the ERPT disconnect Stylized fact 1, it is important to examine wether import prices have a different impact on the consumption price when they affect it directly or indirectly via domestic producers' price. In order to fully apprehend this point, let us poach on Corsetti et al. (2008)'s preserves and derive the structural exchange rate path-through down the pricing chain.

5 Exchange rate pass-through: a structural analysis

5.1 Firms price setting

Intermediate domestic firms act in a monopolistic competition environment and adapt their price to the targeted market. Following Calvo (1983), they reset optimally their price according to the macroeconomic circumstances with a given probability, say ξ_m when exporting and ξ when selling on the domestic market. The corresponding New Keynesian Phillips curves first-order approximations around steady-state are respectively

$$\hat{\pi}_{h,t} = \beta \mathrm{E}_t \hat{\pi}_{h,t+1} - \frac{(1-\xi)(1-\beta\xi)}{\xi}\hat{\mu}_{h,t} \quad , \tag{17}$$

$$\hat{\pi}^*_{f,t} = \beta \mathrm{E}_t \hat{\pi}^*_{f,t+1} - \frac{(1-\xi_m)(1-\beta\xi_m)}{\xi_m}\hat{\mu}^*_{f,t} \quad , \tag{18}$$

$$\text{with } \hat{\mu}_{h,t} = \hat{p}^r_{h,t} - \left[\frac{\eta-1-\delta}{\eta-1}\hat{m}c_{h,t} + \frac{\delta}{\eta-1}\hat{p}^r_{h,t}\right] \quad , \tag{19}$$

$$\hat{\mu}^*_{f,t} = \hat{p}^{*r}_{f,t} - \left[\frac{\eta^*-1-\delta^*}{\eta^*-1}\left[\hat{m}c_{h,t} - \hat{s}_t\right] + \frac{\delta^*}{\eta^*-1}\hat{p}^{*r}_{h,t}\right] \quad . \tag{20}$$

The symbol "*" identifies foreign economy variables. Parameter β represents the psychological discount factor in the domestic economy. Coefficient η is the steady-state value of the price

[18] The upward trend in both import-to-GDP ratios and import content of exports strongly supports the pioneering studies of Feenstra (1998) and Yi (2003) on the rise of foreign value added in domestic production.

elasticity of demand of the firms in monopolistic competition.[19] The aggregate time-varying mark-ups $\hat{\mu}_{h,t}$ and $\hat{\mu}^*_{f,t}$ are determined by the differences between the aggregate price on the targeted market and the drivers of the optimal pricing strategy, all expressed in real terms, i.e. relative to the domestic end-user price $\hat{p}_t$.[20] Under local currency pricing, the latter are the real marginal cost ($\hat{mc}_{h,t}$), expressed in foreign currency for exporting firms through the real bilateral exchange rate $\hat{s}_t$, and the distribution services priced by local firms. Equation (4) indicates that the pricing decision of a firm affects only a share of the retail price on the targeted market, a share that decreases with the importance of distribution requirements. As pointed by Corsetti and Dedola (2005), this reduces the induced variation of market shares compared to what would be implied purely by the demand elasticity, and firms' mark-ups increase accordingly. As such, the price of the foreign distribution services becomes a key element in the exporting firms' pricing decision and dilutes somehow the influence of the exchange rate.

5.2 ERPT at the border

The import price inflation for the domestic economy is actually the foreign export price inflation in domestic currency obtained symmetrically from equations (18), (20) and (5) by switching systematically on/off the "*" symbolizing the foreign economy. We compute the exchange rate pass-through as the coefficient multiplying the contemporaneous exchange rate in the import price Phillips curve when the latter is rewritten in terms of price level instead of price inflation. This allows to obtain measures comparable with Corsetti et al. (2008) who model price stickiness with Rotemberg adjustment costs instead of the Calvo probability. The expressions obtained can be interpreted as a structural elasticity of import prices with respect to exchange rate. It is a *ceteris paribus*, shock invariant, concept as emphasized by Burlon, Notarpietro and Pisani (2018). For the sake of clarity, we operate a clear distinction between the DIST and FIIP assumptions in Proposition 2 below.[21] The fully general case is developed in the technical appendix.

[19] For simplicity, we assume that all the firms, domestic or foreign, selling on the home (resp. foreign) market share the same market power.

[20] In this sense, $\hat{p}^r_{h,t}$ and $\hat{p}^{*r}_{f,t}$ must be read as $\hat{p}^r_{h,t} = \hat{p}_{h,t} - \hat{p}_t$ and $\hat{p}^{*r}_{f,t} = \hat{p}^*_{f,t} - \hat{p}^*_t$.

[21] Note that dealing with intermediate foreign inputs ($\rho_m > 0$) and the distribution sector ($\delta > 0$) at the same time makes the derivation of the pass-through a bit cumbersome. Indeed, the pass-through to domestic producers depends on the pass-through to border prices via ρ_m in the marginal cost, and the reverse holds true via δ in the foreign exporters price mark-up. For this reason, the pass-through to import price requires the computation of the pass-through to domestic price and vice versa. This is made clear in the proof of Proposition 3 (in appendix) but we restrein from this complication in the text.

Proposition 2 *For β^*, β, ξ_m^* and $\xi_m \in [0,1]$, for η and η^* strictly larger than one, for δ and $\delta^* \in \mathbb{R}^+$, the structural exchange rate pass-through towards import price at the border is equal to*

$$
\begin{aligned}
ERPT^{MP}\big|_{\rho_m=\rho_m^*=0} &= \Psi_f \cdot \frac{\eta-1-\delta}{\eta-1} \quad , & (21)\\
ERPT^{MP}\big|_{\delta=0} &= \Psi_f \cdot \frac{1-\frac{\rho_m^*\eta^*}{\eta^*-1}\Psi_f^*}{1-\Psi_f\Psi_f^*\frac{\rho_m^*\eta^*}{\eta^*-1}\frac{\rho_m\eta}{\eta-1}} \quad , & (22)\\
\textit{with} \;\; \Psi_f &= \frac{(1-\xi_m^*)(1-\beta^*\xi_m^*)}{(1-\xi_m^*)(1-\beta^*\xi_m^*)+\xi_m^*(1+\beta^*)}\\
\textit{and} \;\; \Psi_f^* &= \frac{(1-\xi_m)(1-\beta\xi_m)}{(1-\xi_m)(1-\beta\xi_m)+\xi_m(1+\beta)} \quad .
\end{aligned}
$$

Note that

(i) Ψ_f (resp. Ψ_f^*) is decreasing and convex in ξ_m^* (resp. ξ_m);

(ii) $ERPT^{MP}\big|_{\rho_m=0}$ is linearly decreasing in δ. The larger η, the less steep the slope;

(iii) $ERPT^{MP}\big|_{\delta=0}$ is increasing (resp. decreasing) in ρ_m (resp. ρ_m^*).

Proof. *cf. technical appendix.* ■

The pass-through towards import price at the border is limited in the short run by the proportion of firms that do not re-optimise their price. Intuitively, the higher ξ_m^*, the more rigid are prices, and their reaction to changes in the exchange rate is delayed, as emphasized by Smets and Wouters (2002). A larger DIST requirement, δ, makes exporters' mark-up less sensitive to own costs and exchange rate and reduces the pass-through of the exchange rate to the import price at the border. As highlighted by Corsetti and Dedola (2005), the lower the demand elasticity, the stronger the potential of the distribution margin to decrease $ERPT^{MP}$.

Interestingly, both the DIST and FIIP mechanisms allow to obtain a pass-through to import prices at the border that is incomplete under flexible prices, i.e. for $\Psi_f = \Psi_f^* = 1$. For DIST, the reason for the path-through incompleteness lies in the increased mark-up of the foreign exporting firms, as reported supra. For FIIP, the explanation comes from the marginal cost of the foreign exporting firms, that includes a share $\rho_m^*\eta^*/(\eta^*-1)$ of home produced goods. For the latter share, the exchange rate effect on the import price cancels out, as highlighted by Georgiadis, Gräb and Khalil (2019). This is the economic intuition behind items *(iii)* of Proposition 3 that establishes that the pass-through to import price decreases with the integration of home produced goods in the foreign production process. On the contrary, if the Home economy uses more FIIP, the exchange rate is partially cancelled out back and forth, and pass-through increases.

5.3 ERPT towards domestic production price

In models that do not consider FIIP, the relative price of currencies does not affect the domestic price Phillips curve. However, given the internationalization of the production process briefly documented in Section 2, the share of foreign value added contained into a domestic final good is certainly not negligible and increases with the degree of exposure to international trade. In the production process with $\rho_m > 0$, the exchange rate affects the marginal cost of domestic producers via its role in the determination of import prices. The structural pass-through to domestic producers' prices, $ERPT^{DP}$, is equal to the coefficient multiplying the exchange rate in equation (17) when the latter is rewritten in terms of price level rather than inflation.

Proposition 3 *For the same parameters set as in Proposition 2, and for $\xi \in [0,1]$, the structural exchange rate pass-through towards domestic producers price is equal to*

$$\begin{aligned} ERPT^{DP} &= \Psi_h \cdot \frac{\rho_m \eta}{\eta - 1} \cdot ERPT^{MP} \qquad (23) \\ \textit{with } \Psi_h &= \frac{(1-\xi)(1-\beta\xi)^{\frac{\eta-1-\delta}{\eta-1}}}{(1-\xi)(1-\beta\xi)^{\frac{\eta-1-\delta}{\eta-1}} + \xi(1+\beta)} \quad . \end{aligned}$$

Note that (i) Ψ_h is decreasing and convex in ξ and decreasing and concave in δ. The convexity in ξ decreases with η. (ii) $ERPT^{DP}$ increases linearly with ρ_m.

Expression (23) makes clear that the pass-through of the exchange rate to the domestic producers' price is limited twice: first via the combination of nominal and real rigidities that apply to the price dynamics of imported intermediate goods, specified supra, and second, via the combination of nominal and real rigidities that drive the price dynamics of domestically produced goods.

5.4 ERPT towards the consumption price index

All the results gathered at this stage allow to establish some conclusions regarding the transmission of the relative value of the domestic currency to the consumption deflator. They are formally stated in the following Corollaries:

Corollaries of Propositions 1, 2 and 3

- **C0:** equation (16) may be turned into

$$ERPT^{CP} = \phi_c^{m,d} ERPT^{MP} + \left(1 - \phi_c^{m,d}\right) ERPT^{DP} \quad ; \qquad (24)$$

- **C1:** *The parameters affecting the slope of the import price Phillips curve, i.e.* ξ_m^*, η, *and* δ, *make it possible to match any* $ERPT^{MP}$. *International trade in intermediate inputs may also help, through* ρ_m^*, *though his potential is more limited in this respect and is reduced further by* ρ_m *(cf. Proposition 2);*

- **C2:** *for* $\rho_m = 0$, *the relationship between* $ERPT^{CP}$ *and* $ERPT^{MP}$ *is strictly dictated by the import-to-absorption ratio* $\bar{m}/\left(\bar{c}+\bar{\imath}\right)$, *which renders extremely unlikely to match simultaneously the two pass-throughs, notably for large trade exposures. Neither the slope of the import price Phillips curve nor the distribution channel are able to break this linear relationship (cf. Proposition 1);*

- **C3:** *Allowing* $\rho_m > 0$ *rebalances equation (24) away from the import price pass-through towards the domestic production price pass-through. First, FIIP decreases the consumption price pass-through via the dilution effect caused by the domestic production for exports (cf. equation (13)). Second, for FIIP, the nominal rigidity applying for domestic producers selling on the domestic market* (ξ) *complements the nominal rigidity applying for foreign exporters* (ξ_m^*) *and helps waning the CPI pass-through in the short run, keeping the exchange rate inflationnary pressures in the pipeline.*

The combination of the two elements mentionned in Corollary C3 is crucial to reconcile the model with Stylized fact 1: exchange rate fluctuations affect relatively rapidly and importantly import prices at the border, however their impact on the CPI is both strongly reduced and delayed further in time. It stresses the possibility that, in the short run, a relatively more open economy faces a structural consumption price pass-through which does not differ much from that of a less open economy, especially in the presence of significant nominal rigidities in the domestic production sector. The challenge large trade openness poses for the open economy model can thus be addressed by FIIP, which in OECD economies are indeed observed to be strongly positively correlated with trade openness. The direct effect of import prices on the CPI is partially replaced by an indirect effect which domestic firms accommodate through varying mark-ups rather than prices. Noteworthy, in the proposed model, Stylized fact 1 is easier to satisfy with nominal rigidities that are larger for the domestic producers than for the foreign exporters. Is there any rationale for this?

Corsetti et al. (2008) and Huang and Liu (2007) consider a pretty low nominal stickiness, the same for firms both on the domestic and export markets. In this regard, they follow quite literally the micro study by Bils and Klenow (2004) estimating that, in average, firms reset their price after 4.3 months. On the other hand, the nominal rigidity of the domestic New Keynesian Phillips curve is estimated much higher in macromodels like e.g. Christiano, Eichenbaum and Evans (2005) or Smets and Wouters (2007) with firms resetting optimally their price every year on average. The Huang and Liu (2001, 2007) contributions on production chains offer a nice intuition that helps reconcile the discrepancy between macro- and micro-based estimations. In the real world, firms are mostly trading with firms, along a production process made of several intermediate steps and the price of the final good sold to households is only set at the very last stage. The New Keynesian Phillips curve is built theoretically from the horizontal integration of intermediate firms acting in monopolistic competition and totally ignores the vertical integration dimension. As a consequence, the dynamics of the observed macro price series can only be reproduced in the workhorse DSGE model through an overall large estimated producers' price rigidity. It reflects the modelling shortcut and mimics the accumulation of small intermediate price rigidities. The intuition developped in the theoretical works of Huang and Liu (2001, 2007) is confirmed by Smets, Tielens and Van Hove (2018) who incorporate sectoral data and sectors interactions in an estimated DSGE model for the US. They indeed manage to match the strong persistence of consumption price inflation through small estimated price stickiness at the sectoral level that accumulates along the production chain.

However, when intermediate firms export, be it to foreign firms or households, the cross-border price reflects only one stage of production, such that aggregate international price dynamics require much less nominal rigidity to be matched, in line with micro studies. In the absence of more information about intermediate prices, the input-output structure and the average number of production steps, we will rest on the usual simplified New Keynesian representation instead of following Huang and Liu (2007) in a more careful representation of the production stages.[22] In this logic, we consider from now on that, on average, firms reoptimize their price after 4.5 months when exporting ($\xi_m = 0.33$) while they do it only after 4 quarters on the domestic market ($\xi = 0.75$). In the augmented NOEM model, import price inflation

[22] This modelling choice has the advantage to break the implicit link imposed by Huang and Liu (2007) between the number of production stages, i.e. the overall nominal rigidity, and the proportion of foreign intermediate inputs in the production process. They consider that all the firms set their price à la Taylor (1980) for two quarters. At every intermediary stage, there is a requirement for some amount of intermediate foreign inputs. Therefore, increasing the numbers of production steps yields at the same time to more foreign value added in the final domestic production and accumulates price rigidities between the first production step and the final good used for consumption.

affects consumption price inflation directly and rapidly with a weight $\phi_c^{m,d} ERPT^{MP}$, and then indirectly and much more progressively with a weight $(1-\phi_c^{m,d})\Psi_h \frac{\rho_m \eta}{\eta-1} ERPT^{MP}$.

5.5 A numerical illustration

In order to illustrate Corollaries C1-C3, let us give specific values to the most obvious ratios and coefficients to help assess numerically the implication of the pass-through attenuating mechanisms under study for the euro area. In line with the data reported in Figures 2 and 3 (right panel), we set the import-to-absorption ratio equal to 0.26. The parameters appearing in the Phillips curve equations are calibrated at fairly standard values: the discount rate β is set equal to 0.99 and the elasticity of substitution between intermediate goods on markets in monopolistic competition is set equal to 4.5.

The slope of the foreign exporters New Keynesian Phillips curve is a key element to help target the empirically observed short run import price $ERPT$. For the canonical NOEM ($\delta = \rho_m = 0$), yields $ERPT^{MP} = 0.4$ if the import price nominal rigidity Calvo parameter, ξ_m^*, equals 0.33. This value is exactly equal to the import price sensitivity to the exchange rate estimated for France and Germany by Burstein and Gopinath (2014), and is slightly above and not significantly different from the values reported by Özyurt (2016) and Colavecchio and Rubene (2020) for the euro area (respectively 0.35 and 0.33).[23] According to equation (24), the corresponding short run pass-through to the consumption price index is strictly equal to $\phi_c^{m,d} ERPT^{MP} = 0.26 \cdot 0.40 = 0.104$. However, such an $ERPT^{CP}$ is more than twice the 0.04 value reported by Burstein and Gopinath (2014) or Colavecchio and Rubene (2020). As illustrated on Figure 4 (left panel), a lower $ERPT^{CP}$ can be easily reached either by increasing the foreign exporters nominal stickiness ξ_m^* and/or the size of the distribution sector δ. But this solution comes at the cost of a lower structural pass-through to import price as long as the proportionality factor between $ERPT^{MP}$ and $ERPT^{CP}$ is dictated by $\phi_c^{m,d} = \bar{m}/(\bar{c}+\bar{\imath}) = 0.26$. This example illustrates the role and limitation of parameters ξ_m^* and δ emphasized in Corollaries C1 and C2. The difficulty of reconciling the low consumption price pass-through with the high

[23] Not that there is a timing discrepancy between the model structural exchange rate pass-through, which is the one after one quarter, and the estimated ones from the empirical literature, which correspond to pass-through after one year. One might also object that the prices sensitivities estimated in the empirical literature do not correspond to a shock invariant, as highlighted by Corsetti et al. (2008) and Shambaugh (2008). Even though the empirical literature based on single equations price-exchange rate regressions use control variables in the estimation process to get as close as possible to a shock invariant concept, the obtained outcome can nevertheless be viewed as an overall sensitivity, averaged over the different shocks which hit the economy.

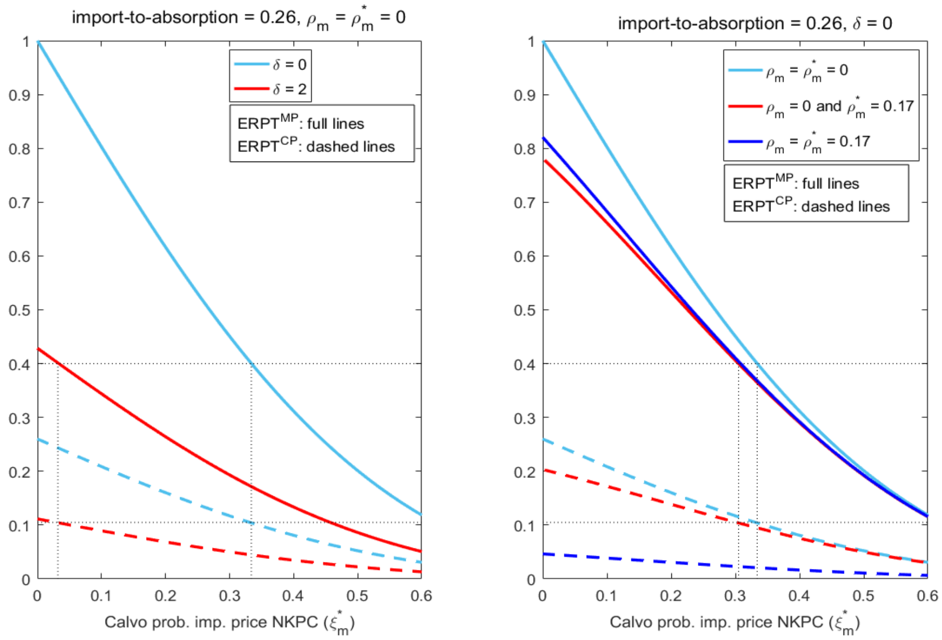

Figure 4: Illustration of Corollaries C1-C3 for the euro area

pass-through to the import price becomes even more severe if we consider a small open economy like Sweden with a twice as big import-to-absorption ratio.

The right panel of Figure 4 illustrates the role of intermediate foreign inputs. First, setting the share of FIIP above zero for the trading partner (ρ_m^*) decreases somehow the import price structural ERPT according to Proposition 2. However, as long as FIIP remains equal to zero in the home economy, it leaves the share of import price in the CPI unchanged at $\phi_c^{m,d} = \bar{m}/(\bar{c}+\bar{\imath})$. When the steady-state FIIP is set to its observed level for the home economy according to the TiVA database (i.e. 0.17 for EA, cf. Figure 2), the proportionality factor between $ERPT^{MP}$ and $ERPT^{CP}$ (respectively the full and dashed blue lines) drops from 0.26 to 0.06 as detailed in Proposition 1. It brings the pass-through disconnect documented in Stylized fact 1 and breaks the link between pass-through to the consumption price and trade-openness, as reported in Stylized fact 2.

6 A structural analysis of the demand for imports

So far, the structural analysis has been entirely focused on the nominal side of the economy. We now consider the real implications of the mechanisms under scrutiny. The demand for imports is driven, first, by the households' absorption and, second, by the firms' production. Beyond this, households and firms take a decision with respect to the Foreign/Home goods and inputs mix based on the relative price of imported compared to domestically produced goods, as reported in equations (7) and (8). Therefore, any mechanism that reallocates imports demand from households to firms and/or that alters the exchange rate pass-through to import prices and to producers' marginal costs and prices, modifies the transmission belt between the nominal and the real side of the economy. This is made clear in the following Proposition, illustrated by Figure 5 below.

Proposition 4 *Substituting for (15) into equation (14) and loglinearizing, the demand for real imports in the Home economy may be written as*

$$\begin{aligned} \hat{m}_t &= (-\lambda_H)\,\Omega_1\,(\hat{p}_{f,t} - \hat{p}_{h,t}) + (-\lambda_m)\,\Omega_2\,(\hat{p}_{f,t} - \hat{mc}_{h,t}) \\ &\quad + (1-\rho_m)\left(\frac{\bar{c}}{\bar{c}+\bar{\imath}}\hat{c}_t + \frac{\bar{\imath}}{\bar{c}+\bar{\imath}}\hat{\imath}_t\right) + \rho_m \hat{x}_t \end{aligned} \tag{25}$$

$$\text{with } \Omega_1 = \left[\frac{1}{1+\delta} - \frac{\bar{m}}{\bar{c}+\bar{\imath}}(1-\rho_m)\right]\left[1 - \frac{\bar{c}+\bar{\imath}}{\bar{m}}\frac{\rho_m}{1-\rho_m}\right] \quad , \tag{26}$$

$$\Omega_2 = \frac{\bar{c}+\bar{\imath}}{\bar{m}}\frac{\rho_m}{1-\rho_m} \quad . \tag{27}$$

According to equations (25), (26) and (27), we have that

(i) FIIP rebalances the demand for imports from private domestic demand towards production and exports;

(ii) $\Omega_1|_{\delta=\rho_m=0} = 1 - \frac{\bar{m}}{\bar{c}+\bar{\imath}}$ *and* Ω_1 *is decreasing and convex in* δ *and decreasing and concave in* ρ_m*;*

(iii) $\Omega_2|_{\rho_m=0} = 0$ *and* Ω_2 *is invariant in* δ *and increasing and convex in* ρ_m*.*

Item (i) is directly related to the aggregate demand externality and items (ii) and (iii) to the terms of trade externality, the two drivers of international spillovers in a trade economy.

The last part of Proposition 4 focuses on the structural coefficients Ω_1 and Ω_2 of the relative prices. They reflect the strength of the expenditure switching effect abstracting from the firms' and households' Armington trade elasticities. Item (ii) emphasizes that the DIST mechanism is able to strongly affect the expenditure switching effect via coefficient Ω_1: the sharp decrease in the weight of the relative price driving the household's import decision following an increase in distribution margins is explained by the concomitant reduction of the share of border prices in the distributed imported price $P^D_{f,t}$ (cf. equation (4)). Noteworthy, no other coefficient of equation (25) moves along with distribution margins. For a given trade openness, as the share ρ_m of FIIP increases, the demand of imports that feeds directly the domestic private demand is replaced by the demand of imports to produce domestic goods that satisfy both domestic and foreign demands. Therefore, the weight Ω_1 of the relative prices driving the households' importing decision and the import sensitivity to domestic private demand declines. By contrast, the weight Ω_2 on the relative prices driving the firm's importing decision gets bigger and the sensitivity of imports with respect to total exports rise. Proposition 4 gives the analytical key to understand the real-nominal interactions in general equilibrium (Section 7) as well as the endogenous international transmission of shocks (Section 8). Before proceeding in this direction, let us focus on the strength of the structural expenditure switching effect which depends both on items (ii) and (iii) of Proposition 4 and on the import prices relative to domestic prices and domestic marginal costs.

Figure 5 illustrates items (ii) and (iii) of Proposition 4 with a numerical example using the calibration adopted so far, i.e. $\bar{m}/(\bar{c}+\bar{\imath}) = 0.26$, corresponding to the euro area. The left panel displays the effect of an increase in the distribution margin $\delta/(1+\delta)$, from 0 to 67 percent. Coefficient Ω_1 that applies to the relative price driving the households' import demand is reduced by a factor 10, falling from 0.74 to 0.07. Coefficient Ω_2 that applies to the relative price driving the firms' import demand is left unchanged. The right panel illustrates the effect of an increase of the steady-state share of FIIP from zero to 20 percent. Coefficient Ω_1 drops from 0.74 to 0.03, but at the same time Ω_2 raises from zero to 0.96 as the demand for imports shifts from a final demand motivation to a production one. We may conclude from these results that both DIST and FIIP reduce the structural expenditure switching effect via coefficient Ω_1 as long as FIIP and domestic value added are complements ($\lambda_m = 0$). However, Values of $\lambda_m > 0$ will tend to dilute the reduction of the expenditure switching effect.

Section 5 was dealing with structural exchange rate path-through and emphasized that the relative prices themselves are sensitive to the slopes of the different Phillips curves. These slopes can be modified through various parameters, among which the nominal rigidity faced by foreign exporters, DIST and FIIP. Therefore, parameters ξ^*_m, δ and ρ_m also affect the expenditure switching effect beyond the respective effect of the latter two on the structural coefficients of the import demand reported in Proposition 4. This observation is summarized in the following Corollaries.

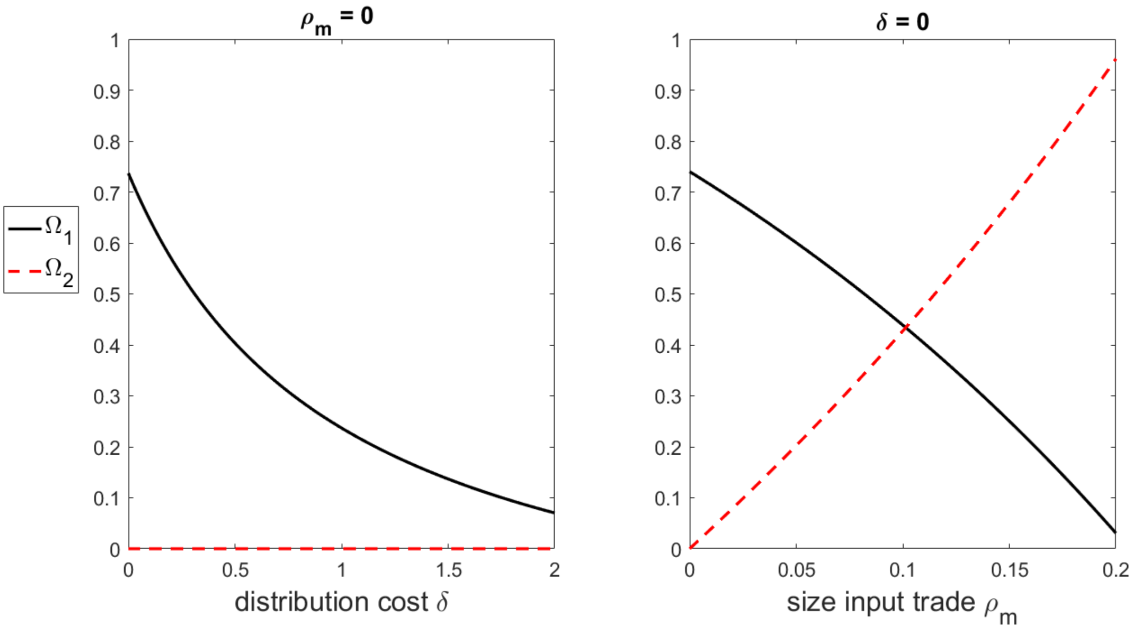

Figure 5: Coefficients driving the imports demand and expenditure switching effect (beside trade elasticities) for $\frac{\bar{m}}{\bar{c}+1} = 0.26$ (euro area).

Corollaries of Propositions 2, 3 and 4:

For $\frac{\bar{m}}{\bar{c}+\bar{\imath}}$ *and* $\delta \in \mathbb{R}_+$, *and for* $\rho_m \in [0,1]$

- **C4 (on border prices nominal stickiness):** *A weaker slope of the import price Phillips curve obtained via parameter* ξ_m^* *affects the relative prices driving the households and firms decisions, but not their weight in the overall import demand decision;*

- **C5 (on DIST):** *Beside its effect on* Ω_1, *a weaker slope of the import price Phillips curve obtained via parameter* δ *(cf. Proposition 2) structurally limits variations in the relative price driving households and firms imports demands as domestic prices substitute out the exchange rate in the mark-up of foreign exporting firms;*

- **C6 (on FIIP):** *Beside its effect on* Ω_1 *and* Ω_2, *a larger share of FIIP structurally limits variations in the relative price driving households and firms imports decisions by raising the share of import prices in the domestic producer's marginal cost.*

Proposition 4 and Corollaries C4 to C6 focus on the import demand of the Home economy. They can also be applied to the Foreign economy to assess the role played by parameters ξ_m, δ^*, ρ_m^* and λ_m^* in determining the exports of the Home economy. Exports are indeed an important component of the Home production, and as such, they contribute to the pressures implied by an appreciation/depreciation of the currency on the demand for domestic production factors and on their remuneration. The latter remains the most important driver of the domestics firms' marginal cost. The last observation calls for a dynamic general equilibrium analysis.

On top of the structural effects that can be assessed directly via the equations of the model and a partial equilibrium analysis, the prices' dynamics are also mitigated through general equilibrium loops closely related to the overall - i.e. both in the Home and Foreign economies - expenditure switching effects between imported and domestically produced goods. This is scrutinized further in the following paragraphs.

7 A general equilibrium two-country application

A general equilibrium exercise requires to build a comprehensive macroeconomic set-up. We rely on a symmetric two-country model built by combining the equations presented in Section 3 and 5 for the open economy variables with Smets and Wouters (2007) for the domestic variables.[24] In order to focus on the differences in dynamic responses due to the chosen assumption regarding (i) the slope of the Phillips curve, (ii) DIST and (iii) FIIP, the model is calibrated for the euro area and the partner economy is assumed to be fully symmetric, sharing all the parameters that are made explicit in the Calibration Appendix.[25] Without loss of generality and for the benefit of the exercise, let us fix λ_H, the Armington elasticity of substitution between imported and domestic retail goods at 3, a value close to the one estimated by de Walque et al. (2017) for the period 1970Q1-2014Q4.[26] The log-linearized uncovered interest rate parity condition is given by

$$\hat{S}_t = \mathrm{E}_t \hat{S}_{t+1} + \hat{r}_t^* - \hat{r}_t - \rho_n n\hat{f}a_t + \varepsilon_t^s \quad , \tag{28}$$

where $\hat{S}_t$ represents the nominal exchange rate in relative deviation from steady-state, $\hat{r}_t^*$ is the absolute percentage variation of the foreign short-term nominal interest, and $\hat{r}_t$ its home

[24] It is actually a simplified calibrated version of de Walque et al. (2017).

[25] The households CES equation (2) composing the end-users bundles from home and foreign goods and the equivalent CES production function for price setting firms are augmented with an adjustment cost as in Erceg, Guerrierri and Gust (2006) in order to smooth somehow the expenditure switching.

[26] Such a value is admittedly high compared to the trade elasticities usually found in the NOEM literature, that are usually around unity. However, it is not the value of the elasticity per se which is of interest, but how its implications in terms of expenditure switching effect are modified by the different variants examined. A careful analysis of the interaction between the trade elasticities and the two mechanisms studied here - input trade and distribution - is one of the topics of an estimated sequel of the present paper.

counterpart. $n\hat{f}a_t$ is the percentage deviation with respect to steady-state of the domestic holdings of net foreign assets, ensuring the solution stability.[27] Finally, ε_t^s is an auto-regressive process of order one, capturing exogenous variations in international financial market conditions. Beside ε_t^s, any shock in the domestic or the foreign economy that affects one of the interest rates through the reaction of the monetary policy, will modify the bilateral exchange rate. The monetary policy is represented by a Taylor rule based on Smets and Wouters (2007):

$$\hat{r}_t = \rho_r \hat{r}_{t-1} + (1-\rho_r)\left(\rho_\pi \hat{\pi}_{c,t} + \rho_{yg}\hat{y}_t^g\right) + \rho_{\Delta yg}\left(\hat{y}_t^g - \hat{y}_{t-1}^g\right) + \varepsilon_t^r$$

where $\hat{y}_t^g$ represents the differential between real domestic value added and potential domestic value added measured as the GDP prevailing in a counterfactual economy with flexible prices and wages.

7.1 Dynamic responses to an unexpected depreciation

As the first objective of the present contribution is to deal with the exchange rate pass-through, it seems natural to start the exercise with the study of the macroeconomic dynamics after an unexpected depreciation of the home currency. The persistence of the UIP autoregressive process ε_t^s is set equal to 0.80 and the size of the shock is chosen to generate a depreciation by one percent on impact for the benchmark calibration where $\delta = \rho_m = 0$. The UIP shock has the distinctive feature to be common to both economies and the full symmetry assumption adopted supra implies that the reaction of the Foreign economy exactly mirrors this of the Home economy. Let us observe and discuss the implications of departing from the benchmark model by (i) increasing nominal rigidities for exporting firms, and introducing (ii) DIST and (iii) FIIP. The impulse response functions obtained for the variants considered are displayed on Figure 6 and 7.

7.1.1 About the import price nominal stickiness

In the benchmark simulation (black line), DIST and FIIP are absent and thus the slope of the import price Phillips curve is determined solely by the Calvo probability of not re-optimizing, ξ_m^*, which is set to 0.33 such that $ERPT^{MP} = 0.40$ and $ERPT^{CP} = 0.10$ (cf. Figure 4). The difference between import and producers' prices in the Home (resp. Foreign) economy triggers a strong reallocation of the global demand away (resp. towards) from Foreign (resp. Home) goods.

[27] See e.g. Schmitt-Grohe and Uribe (2001).

The surge in Foreign demand for Home produced goods more than compensates the negative effect of imported inflation on Home private absorption and pushes domestic producers' price upwards.

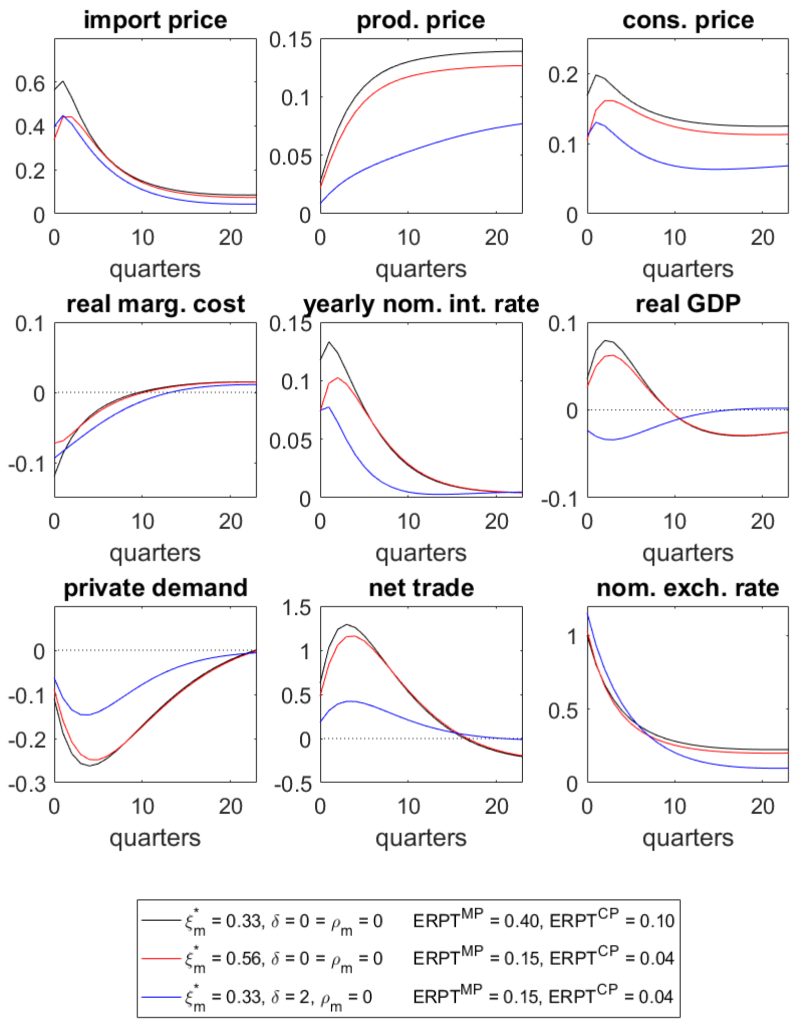

Figure 6: EA impulse responses to a 1% euro depreciation

import price nominal stickiness vs distribution

The full red line on Figure 6 displays the consequences of increasing the Calvo probability to 0.56, which corresponds to an average price duration of 7 months instead of the initial 4.5. This change more than halves the structural pass-throughs, such that $ERPT^{MP} = 0.15$ and $ERPT^{CP} = 0.04$. The nominal rigidity ξ_m^* determines the hump-shaped profile of the import price reaction which is directly transmitted to the consumption price. A flatter import price Phillips curve lowers the increase in the price differential caused by the depreciation, thereby limiting somewhat the expenditure switching effect and the general equilibrium forces that generate inflation in the domestic producers' price. Given the weight of the latter $(1 - \phi_c^{m,d} =$

0.74) in the consumption price index, this efficiently supplements the delayed reaction of import price to limit the transmission of exchange rate to consumption price.

As already stated in the related literature, the low pass-through to consumption price obtained via the nominal stickiness in the import price Phillips curve is reached at the cost of a (unrealistically) low transmission of the exchange rate to import price in the short run. In other words, it does not improve the models ability to match the ERPT disconnect documented in Stylized fact 1. This is one major argument on whose ground Corsetti et al. (2008) to introduce a distribution sector à la Burstein et al. (2003). Let us observe in our dynamic framework whether their intuition is indeed verified, how and why.

7.1.2 About the effect of DIST

For the baseline import price Calvo parameter of 0.33, a structural pass-through to consumption price of 0.04 and thus in line with the empirical evidence can be obtained by considering a distribution margin $\delta/(1+\delta)$ equal to 0.67. As stated in Corollary C5, at a given trade openness, the size of the distribution sector alters the import demand. First, it attenuates the import sensitivity to the relative price driving the household import demand, Ω_1, which is reduced by a factor ten compared to the benchmark (cf. Figure 5, left panel). Second, it partially substitutes in the Foreign exporters' mark-up their own marginal cost and the exchange rate for the price of Home distribution services, reducing the relative price gap between Foreign and Home goods caused by an exchange rate depreciation. Both elements joinly limit sharply the expenditure switching effect. The impulse responses to a UIP shock (full blue lines) drawn on Figure 6 for the net trade and real GDP display how the mechanism wipes out the expansionary effect of a depreciation. This sharp decrease in overall demand compared to the benchmark goes along with a much more contained increase in domestic producers' prices through general equilibrium effects.

It turns out that the reduced pressure on producers' prices compared to the canonical model is responsible for the muted reactions of both the import price and the consumption price. According to equation (20), the domestic producers' price represents $\delta/(\eta-1) = 57$ percent of the foreign exporters' mark-up, and it accounts now for 80 percent of the consumer price, computed as $(1-\phi_c^{m,d}) + \phi_c^{m,d}\Psi_f\frac{\delta}{\eta-1}$. Figure 6 emphasizes that the DIST mechanism is much more efficient than import price nominal stickiness to obtain a low and delayed transmission of exchange rate fluctuations to consumption price. This is mostly due to the way it affects the demand for real imports in the Home and Foreign economies: a lower trade balance surplus from the unexpected devaluation implies a lower expected upwards pressure in the labour market that ends up in lower domestic firms marginal cost and prices. Proposition 4, Corollary 5 and the implied general equilibrium effects are key in this outcome.

However Figure 6 also illustrates that the general equilibrium mechanisms at work do not strongly modify the conclusion stated in Corollary C1 for a static environment. The lower transmission of exchange rate towards consumption price goes along with a substantial decrease of the transmission to import price, as illustrated by the impulse response for import price.[28]

As such, when estimating an open economy model, the Calvo parameter, ξ_m^*, would help capture the import price dynamics, the size of the distribution sector, δ, may supplement the trade elasticity λ_H in dealing with some features of the observed real series, but none of them offers a credible potential to reconcile the high exchange rate/import price connectedness with the low transmission of currency price to consumption prices. This is not an astonishing conclusion as the very essence of both mechanisms is to bring the import price dynamics closer to the producers' price one, reducing the relative price gap.

7.1.3 About FIIP and the role of inputs substitutability (λ_m)

We now examine the impact of FIIP on the effect of a depreciation. As above, the black line represents the baseline case without FIIP, which we compare to two economies where parameter ρ_m is set to 0.17. Let us first consider an economy where firms and households share the same value for their respective Armington trade elasticities: $\lambda_m = \lambda_H = 3$ (full blue lines on Figure 7). With FIIP, the domestic marginal cost becomes directly sensitive to import prices and this is translated into the producers' price. Concurrently, for the chosen calibration, the respective weights of import and domestic producers' prices into the consumption price index, i.e. $\phi_c^{m,d}$ and $1 - \phi_c^{m,d}$ equal 0.06 and 0.94 , respectively, instead of the 0.26/0.74 partition prevailing in the benchmark economy ($\delta = \rho_m = 0$, black lines). For the share $\rho_m/(1-\rho_m)$ of imports that enters the consumption price index indirectly, the impact of the exchange rate shock on the price of domestic production is diluted twice. First through the relatively steep import price Phillips

[28] This can also be displayed using the Shambaugh (2008) shock dependent price-to-exchange-rate ratios ($PERR$) indicators: $\hat{p}_l^s/\hat{s}_t^s$, $l \in \{f, c\}$, where suffix s indicates the variable's impulse response to the UIP shock. Reducing the gap between import and consumption prices at the retail level either via a flattening of the import price Phillips curve only (full red line) or through distribution services (full blue line) pushes down the $PERR$ concept of consumption price pass-through but at the cost of an *ab initio* strong deformation of the import price $PERR$ ratio.

curve ($\xi^*_m = 0.33$), as in the baseline economy, and second via the much flatter domestic price Phillips curve ($\xi = 0.75$).

Compared to the baseline (black lines) economy, the depreciation is less inflationary and the real private home (resp. foreign) demand reacts less negatively (resp. positively). The net trade reaction is also somewhat reduced as firms need foreign inputs to satisfy the foreign demand, even though they partially substitute them by domestic inputs. Both elements mostly offset each other and, overall, the GDP dynamics is nearly identical to the benchmark.

What happens if there is less substitutability between Home and Foreign components at the firms than at the households level? In the extreme case of perfect complementarity (blue dashed lines) between Home and Foreign inputs in the production process ($\lambda_m = 0$ in equation (15)), only (Home and Foreign) households remain sensitive to relative price effects. Compared to the benchmark economy, the weight Ω_1 of this relative price in the global import demand melts down from 0.74 to 0.17 (cf. Figure 5). Under perfect complementarity this is not compensated anymore by the firms' sensitivity to relative price. As a result, the euro depreciation leads to a much more contained trade balance improvement under pure complementarity than under substitutability at the firm level and the depreciation is much less beneficial to the economic activity of the home economy. This has consequences on the labour market with lower wage pressures yielding a lower reaction of the real marginal cost and price of the domestic producers.

All in all, the general equilibrium mechanisms at work imply that less substitutability between Home and Foreign inputs in production lead to less inflation in the price of domestic firms in the aftermath of a currency depreciation, and consequently a lower pass-through towards CPI. It is quite remarkable that, taking seriously general equilibrium mechanisms into account, totally reverses the conventional wisdom conveyed by the partial equilibrium reasonning of Campa and Goldberg (2010) who state: "*Calibrated price effects of exchange rates and import prices are smaller when economies can more flexibly substitute away from imported components into domestic components when producers are confronted with an adverse cost shock*".

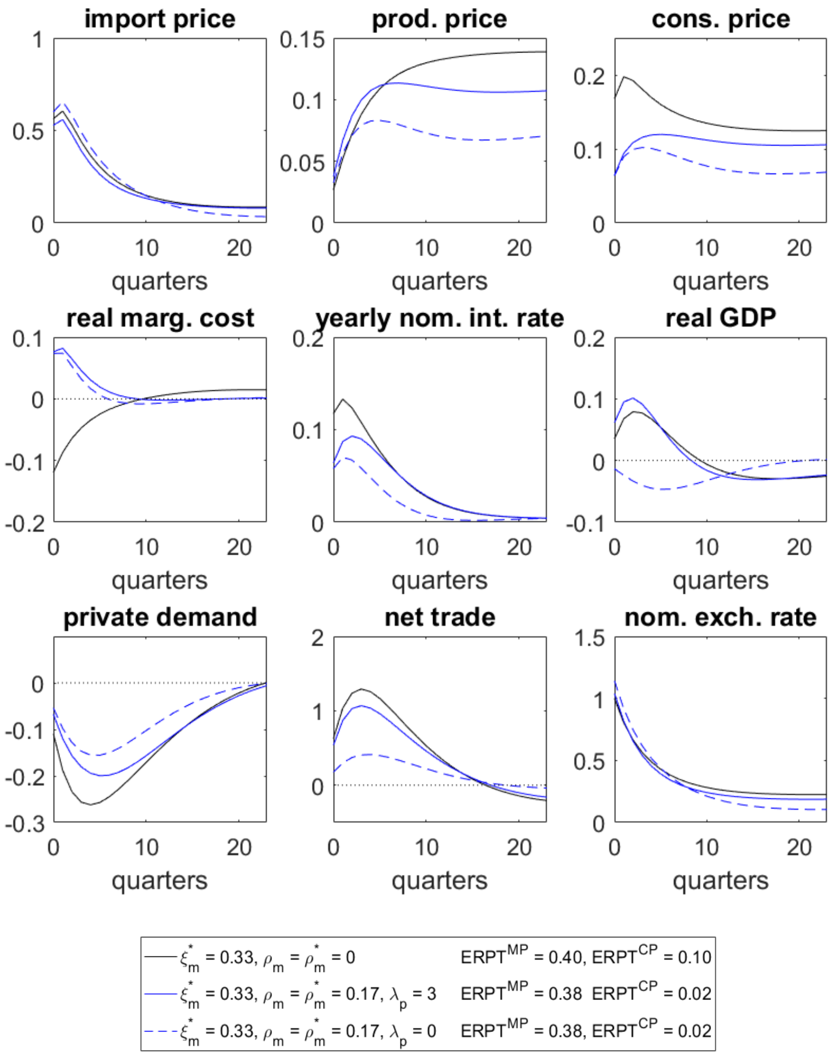

Figure 7: EA impulse responses to a 1% euro depreciation

FIIP and firms' inputs substitutability

We may summarized our outcomes as follow. First, compared with the canonical NOEM, inputs trade is the only modelling device covered by the present study that helps efficiently to solve the puzzle of a high pass-through to prices at the border and a low one to prices at the consumption level, whatever the considered degree of inputs substitutability at the firm level. Second, when assessing the effect of inputs substitutabiliy on the pass-through to the consumption price, the general equilibrium consequences of the expenditure switching effect for domestic producer prices ruin the conventional intuition based on a partial equilibrium reasoning à la Campa and Goldberg (2010). Finally, it is worth to remark that, as both the DIST and FIIP ($\lambda_m = 0$ case) mechanisms reduce the expenditure switching effect, they also challenge the traditionnal view that that devaluations are growth enhancing, in line with recent empirical evidence of Lane and Stracca (2018).

8 On international spillovers

Using the structural import equation (25) as a starting point, we now examine the impact of the FIIP and DIST on the ability to generate cross-country spillovers. Obstfeld and Rogoff (1995) state that the international real transmission of a country specific shock depends on the aggregate demand externality, on the one hand, and on the terms of trade externality, on the other hand. The aggregate demand elasticity is captured by the final two terms of equation (25) and elicits a positive correlation between the real activities of the two trading economies. The terms-of-trade externality is captured by the remaining terms, which depend on relative prices and may either enhance or oppose the aggregate demand externality depending on the implied reaction of the exchange rate via the UIP relationship. In this sense, the expenditure switching effect is not only important in shaping the transmission of exchange rate movements to consumption prices along the pricing chain, but it is also crucial in determining the ability of a model to generate international co-movements, as formalized in the following corollary.

Corollary C7 to Proposition 4 *(i) In a two-country symmetric framework, any mechanism that reduces the expenditure switching effect mitigates the terms of trade externality. This enhances (resp. limits) the international synchronization of real business cycles in the aftermath of country specific shocks to which the country policy interest rate evolves countercyclically (resp. procyclically). (ii) According to the last two terms of equation (25), FIIP modifies structurally the aggregate demand externality compared to the canonical NOEM, while DIST does not. As the direct effect of a country-specific shock on the private domestic demand is likely to be larger than its consequences on the import demand of the trading economy, one may expect DIST to be more efficient than FIIP in eliciting real synchronization, whatever the considered shock.*

Let us consider the pure exchange rate shock studied in Section 7 that affects both economies in an inverse way. Inflation increases in the economy with a depreciated currency, depressing its domestic absorption. The larger the expenditure switching effect, the more this economy adjusts imports downwards and exports upwards, increasing the chance that depreciation is growth enhancing. As the reverse holds for the trade partner, country specific inflations and outputs diverge. For this particular shock, any mechanism able to reduce the expenditure switching effect attenuates the discrepancy as illustrated on Figures 6 and 7.

Following Obstfeld and Rogoff (1995), the reasoning may be extended to assess ex-ante the international consequences of any country-specific shock, relying on the UIP condition. A non-policy shock that pushes the Home private demand upwards requires more Home and Foreign production. This is the usual aggregate demand externality. If the monetary authority lowers its policy rate in response, it boosts the increase in Home economic activity through the implied devaluation, which lowers exports and economic activity of the Foreign economy. The same reasoning applies to an expansionary monetary policy shock This is the so-called terms of trade externality. Again, the larger the expenditure switching effect, the more the terms of trade externality foils the aggregate demand externality, reducing the capacity of the model to generate ample real co-movements. By contrast, an increase in the policy rate and the resulting appreciation of the currency will attenuate the increase in home output and boost foreign exports and economic activity. For such shocks, the larger the expenditure switching effect, the stronger the endogenous real co-movement in GDP.

According to this typology, one expects that all the mechanisms mentioned in Corollaries C4-C6 contribute to improve the capacity of a model to generate endogenous co-movements by reducing the terms of trade externality after country-specific monetary policy shocks, productivity shocks and mark-up shocks.[29] On the contrary, they would hinder this possibility in the aftermath of demand shocks in general. However, note that for shocks emanating directly from the demand for consumption and investment, the aggregate demand externality plays an important role. A mechanism that downsizes the elasticity between import and domestic private demand would inevitably reduce further the potential for demand shocks to drive real business cycles coordination.

We now illustrate how DIST and FIIP affect the aggregate demand and terms of trade externalities by using the symmetric two-country model of Section 7 by running simulations for different types of shocks. The results of these experiments are displayed in Tables 1 and 2 below, the first one focusing on monetary and technology shocks, and the second one on both risk-premium shocks à la Smets and Wouters (2007)[30] and consumption preference shocks.[31] The persistence of the exogenous shock processes are fixed at conventional values in the literature. The two tables report cross-country shock-dependent correlations for real GDPs and consumption prices, and the within country shock-dependent correlations between imports and exports, and between changes in the nominal exchange rate and import price inflation, on the

[29] Following this reasonning, the results obtained in Proposition 4 regarding the role of the demand elasticity of the CES domestic production function are fully coherent with the conclusion of Burnstein et al. (2008) for productivity shocks, i.e., that low substitutability increases the potential of input trade to elicit real business cycle synchronization.

[30] i.e. a shock on the differential between the risk free rate fixed by the central bank and the one actually paid by the houdeholds.

[31] i.e. a shock on the rate at which households discount their future instantatenous utilities.

one hand, and consumption price inflation, on the other hand. The goal of the exercise is not to reproduce some cross-correlations and relative standard deviations observed for a particular economy, which would require to carefully calibrate the relative standard deviations of the different shocks considered. Instead, for each of the four considered shocks, we aim to illustrate numerically Corollary C7 by jumping accross the different variants of the NOEM considered in the paper. For each of them, we analyse through which channels it helps to improve the canonical model to better reproduce some general features of the data, in particular regarding its capacity (i) to get cross border correlations in real GDP and consumption prices, (ii) to obtain an as large as possible correlation between imports and exports and (iii) to cope with Stylized fact 1.

On country-specific monetary policy shocks

As expected from the previous discussion, the canonical model with no-DIST-no-FIIP performs poorly in terms of cross-border GDP correlations if we consider that the trading economies are hit uniquely by uncorrelated country-specific monetary policy shocks. Such shocks affect heavily the relative price of currencies via the UIP condition and the terms of trade externality counteracts severely the aggregate demand effect. The strong expenditure switching effects dampen the volatility of imports in the economy hit by the shock and amplify it for the trading partner. This helps imports and exports to co-move in each economy. Finally, Home and Foreign consumption prices are negatively correlated: in the Home economy surprised by a hike in the policy rate, prices are pushed downwards directly in reaction to the shock, and indirectly through the ensuing currency appreciation. In the Foreign economy, the effect of the (Foreign currency) depreciation prevails, and the consumption price increases.

More nominal stickiness at the import price level reduces somehow the connection of import prices with the exchange rate, and via this channel, this of consumption prices. This improves the cross-border correlation of consumption prices inflations. The reduction of the expenditure switching effect obtained via the sole relative prices helps only marginally to increase the GDPs' co-movement.

The introduction of DIST does also reduce the conditional correlation between consumer price inflation and exchange rate variations. As for the UIP shock (cf. Figure 6, full blue line), this outcome is obtained at the cost of a reduction of the link between import price and currency price. DIST allows to improve strongly the GDPs synchronization by reducing the expenditure switching effect, as expressed in Proposition 4. However, this happens at the cost of the correlation between imports and exports in each economy. For the chosen calibration, it does not help much to obtain more cross-border CPI co-movements.[32]

By contrast, FIIP improves substantially the cross-border correlation of the consumption price indices. Whatever the degree of substitutability between Home and Foreign inputs in the production process (measured by λ_m), FIIP reduces the consumer prices-exchange rate connection while leaving the import prices strongly correlated with the relative price of currency. By keeping a substantial share of the exchange rate variations longer in the domestic Phillips curve pipeline, FIIP improves substantially the cross-border correlation of the consumption price indices.

Furthermore, as long as perfect complementarity is assumed at the firm level, FIIP also efficiently induces endogenous co-movements in real activity, confirming the results obtained by Huang and Liu (2007). However, in their multi-stage production sector with firms setting prices according to fixed duration Taylor contract, these authors develop a set-up in which the importance of intermediate foreign inputs raises together with overall producers' price stickiness. We show that their results for GDPs synchronization still hold with a constant slope for the aggregate Phillips curve of the production sector. By contrast, if the expenditure switching effect is revitalized via the substitutability between Home and Foreign intermediate inputs, the cross border GDP synchronization collapses, in line with Corollary C7.

Finally, FIIP boosts the correlation between exports and imports, regardless of the degree of substitutability between inputs at the firm level. The reason for the stronger correlation is that, given the share of imports in GDP, FIIP moves imports out of the final domestic goods basket and into production, part of which is exported.[33] However, compared with DIST, this limits somewhat the aggregate demand externality: in the case of a monetary policy shock in the Home economy, the private Home absorption reacts much more than the Foreign demand for Home goods which explains the relative poorer performance in terms of real GDPs coordination.

[32] Even though the consumer price standard deviation is reduced in both economies, the CPIs dynamics still mirror each other importantly.

[33] Nevertheless, for the reasons sketched above, more expenditure switching effects via a larger trade substitutability imply a stronger imports-exports interconnection.

Table 1. Simulated correlations for mon. pol. and prod. shocks

	$\xi_m^* = 0.33$ $\delta = 0 = \rho_m$	$\xi_m^* = 0.56$ $\delta = 0 = \rho_m$	$\xi_m^* = 0.33$, $\rho_m = 0$ and $\delta = 2$	$\xi_m^* = 0.33$, $\delta = 0$ and $\rho_m = 0.17$	
				$\lambda_m = 0$	$\lambda_m = 3$
	Monetary policy shocks (i.i.d.)				
$corr(\hat{y}_t, \hat{y}_t^*)$	0.07	0.12	0.42	0.31	−0.03
$corr(\hat{x}_t, \hat{m}_t)$	0.42	0.59	−0.13	0.51	0.69
$corr(\hat{\pi}_{c,t}, \hat{\pi}_{c,t}^*)$	−0.43	−0.27	−0.29	−0.17	−0.21
$corr(\hat{\pi}_{f,t}, \Delta\hat{s}_t)$	0.94	0.83	0.91	0.94	0.94
$corr(\hat{\pi}_{c,t}, \Delta\hat{s}_t)$	0.74	0.57	0.65	0.47	0.47
	Total factor productivity shocks (AR1: 0.9)				
$corr(\hat{y}_t, \hat{y}_t^*)$	0.13	0.14	0.60	0.55	−0.03
$corr(\hat{x}_t, \hat{m}_t)$	0.09	0.09	0.41	0.91	−0.06
$corr(\hat{\pi}_{c,t}, \hat{\pi}_{c,t}^*)$	0.78	0.90	0.40	0.70	0.76
$corr(\hat{\pi}_{f,t}, \Delta\hat{s}_t)$	0.72	0.61	0.84	0.79	0.63
$corr(\hat{\pi}_{c,t}, \Delta\hat{s}_t)$	0.30	0.11	0.33	−0.10	−0.09

ξ_m^*: Calvo probability of not reoptimizing import price, δ: proportion of distribution services per unit of final good, ρ_m: proportion of foreing inputs for the production of one intermediate good, λ_H and λ_m: Armington trade elasticity for households and firms respectively

Note: the model has been simulated for 6000 periods and the moments are computed discarding the first 500 ones.

On country-specific productivity shocks

A positive Home technology shock depresses the producers' price and the central bank reacts by decreasing its policy rate, depreciating the Home currency. The implied movements in import prices mitigates somehow the drop in Home consumption prices while it decreases Foreign consumption prices, yielding a positive wealth effect. For the canonical NOEM calibration (left column of Table 1) such a shock generates some real GDP international co-movement and an important correlation in CPI inflations. It is important to note that, in the Home economy, the drop of producers' prices with respect to import prices implies a strong reallocation of demand between Home and Foreign goods. The same occurs in opposite direction in the Foreign economy, though to a lower extend as the initial Home shock does not directly hit the Foreign firms' marginal cost. In the Home (resp. Foreign) economy, GDP growth is enhanced (resp. mitigated) by the net exports, and, as a result, imports and exports are weakly correlated in both economies. When the import price Calvo stickiness is increased from 0.33 to 0.56, the expenditure switching effect is only affected through relative prices and real synchronization is not much altered. On the nominal side, the increased nominal rigidity in import price modifies the timing of the above described import price effect on consumption prices such that CPI inflations are even more synchronized.

The DIST channel strongly decreases the expenditure switching effect along the lines described in Proposition 4, tuning down the terms of trade externality and improving strongly real co-movements. With international trade mostly driven by private aggregate demands, imports and exports movements are much more correlated in both economies than in the canonical model. This also has the consequence to enhance the demand for production factors in the economy that is not hit by the positive technology shock, moving further the marginal costs of both economies in opposite directions, which contributes to disconnect somehow their respective consumption prices dynamics.

Input trade produces very similar outcomes than distribution costs on the real side: under perfect complementarity of Home/Foreign intermediate inputs, the terms of trade externality is strongly reduced and real outputs synchronization is enhanced.[34] As discussed by Burstein, Kurtz and Tesar (2008) for technology shocks in an RBC framework, and for the reasons made explicit in Proposition 4 hereabove, the more firms have the possibility to switch between foreign and domestic inputs, the lower the cross-border real correlation. Due to the chosen nominal stickiness, technology shocks weight stronger on the marginal cost of the hit economy than on the price of its domestic producers. This explains why, when setting the trade elasticity at the same level for the households' utility and the firms' technology, the import demand reallocation following relative prices movement is larger for firms and the correlation between imports and exports decrease with respect to the canonical model. On the contrary, combining FIIP with a Leontief Home-Foreign inputs technology does not only neutralize the terms of trade externality, but boosts further the imports-exports connection through the requirement of imported inputs. On the nominal side, the FIIP story is quite different from the DIST one. The home currency depreciation rises the price of the foreign intermediate input, braking the drop of domestic producers' marginal cost. At the same time, the share of import price in the CPI index drops from 0.26 to 0.06, closing down the CPI-exchange rate correlation independently of the degree of substitutability between Home and Foreign intermediate inputs.

[34] Even though somewhat less than under the DIST mechanism, due to the above mentioned modification in the composition of aggregate demand externality (equation (25)).

On country-specific risk-premium shocks

Table 2 displays the same co-movements statistics for a Smets and Wouters (2007) risk-premium shock, i.e. a shock that drives a wedge between the central bank risk-free rate and the interest rate actually faced by households. Such a shock has the distinctive feature of moving investment, consumption and the policy rate in the same direction. A decline in the risk-premium expands the Home economy and appreciates the exchange rate, implying that both the aggregate demand and the terms-of-trade externalities expand home imports and foreign exports. Furthermore, foreign imports decrease due to higher import prices, implying an increase in economic activity, in spite of lower domestic demand due to a higher policy rate. Thus the strong positive GDPs correlation is entirely driven by the respective net trades that slow down the Home real activity and encourage the Foreign one, as reflected by the negative correlation between imports and exports.

Any mechanism that reduces the terms of trade externality tends to decrease at the same time the GDP positive correlation and the imports-exports negative one. For the same reasons as those already given for the previous shocks, the variant of the NOEM endowed with DIST does a better job in terms of cross-border GDPs correlation than with FIIP entering as complements. The opposite is true for the within country imports-exports interconnection, which is larger with FIIP as complements.

Finally, With FIIP (last two columns on the right), the decrease in Home import price implied by the initial shock affects the producers' marginal cost and attenuates their price increase compared to the other model variants. This is translated in the CPI index with a larger weight as the share of domestic producers' prices increases from 0.74 to 0.94, reducing the drastically the conditional correlation between consumption price and exchange rate and eliciting cross-border CPIs' correlation.

Table 2. Simulated correlations for demand-like shocks

	$\xi_m^*=0.33$	$\xi_m^*=0.56$	$\xi_m^*=0.33$ and $\rho_m=0$	$\xi_m^*=0.33$ and $\delta=0$	
	$\delta=0=\rho_m$	$\delta=0=\rho_m$	$\delta=2$	$\rho_m=0.17$	
				$\lambda_m=0$	$\lambda_m=3$
	Risk-premium shocks (AR1 0.2)				
$corr(\hat{y}_t,\hat{y}_t^*)$	0.63	0.63	0.56	0.41	0.55
$corr(\hat{x}_t,\hat{m}_t)$	−0.48	−0.41	−0.14	0.20	−0.05
$corr(\hat{\pi}_{c,t},\hat{\pi}_{c,t}^*)$	0.64	0.87	0.74	0.89	0.94
$corr(\hat{\pi}_{f,t},\Delta\hat{s}_t)$	0.73	0.61	0.69	0.76	0.70
$corr(\hat{\pi}_{c,t},\Delta\hat{s}_t)$	0.39	0.20	0.29	0.02	0.03
	Preference shocks (AR1 0.9)				
$corr(\hat{y}_t,\hat{y}_t^*)$	0.56	0.55	0.48	0.39	0.50
$corr(\hat{x}_t,\hat{m}_t)$	−0.79	−0.78	−0.08	−0.45	−0.83
$corr(\hat{\pi}_{c,t},\hat{\pi}_{c,t}^*)$	0.44	0.70	0.15	0.62	0.89
$corr(\hat{\pi}_{f,t},\Delta\hat{s}_t)$	0.85	0.71	0.89	0.90	0.83
$corr(\hat{\pi}_{c,t},\Delta\hat{s}_t)$	0.51	0.34	0.52	0.14	0.27

ξ_m^*: Calvo probability of not reoptimizing import price, δ: proportion of distribution services per unit of final good, ρ_m: proportion of foreing inputs for the production of one intermediate good, λ_H and λ_m: Armington trade elasticity for households and firms respectively

Note: the model has been simulated for 6000 periods and the moments are computed discarding the first 500 ones.

On country-specific consumption preference shocks

For consumption preference shocks,[35] consumption and investment react in opposite directions in the hit country, even though the aggregate domestic demand remains dominated by consumption. In the canonical NOEM, this has one important consequence: in the hit economy, the absorption reacts in with a hump-shaped profile instead of the more abrupt jump observed for the risk-premium shock. This mirrors much more the profile of the trading partner's domestic demand. Given that absorption is a major determinant of imports, imports and exports react in a close - though inverted - way, such that the within country negative correlation between imports and exports is enhanced compared to risk-premium shocks. With FIIP, the absorption motive for imports is partially replaced by a production/exports motivation, and the overall imports reaction comes closer to the hump-shaped profile of exports. This explains

[35] The same holds true for investment relative price shocks (not shown here).

why FIIP is much less efficient in breaking the negative imports-exports correlation conditionnal on consumption preference shocks than on risk-premium shocks. Regarding the pass-through disconnect and the cross-country correlation of the CPIs, conclusions are left unchanged: FIIP is definitely more efficient than the DIST assumption.

9 Conclusion

In the previous lines we have tried to better understand the respective macroeconomic implications of a distribution sector à la Burstein et al. (2003) and of the inclusion of foreign inputs in production à la Burstein et al. (2008) in the New Keynesian open economy set-up. So far, in the literature the two mechanisms have been studied separetely. Both are close in their philosophy which is to refine the way Home and Foreign goods are mixed in the retail final good bundle compared to the canonical Gali and Monacelli (2005) NOEM. We emphasize that the critical difference between the two modelling schemes is the link of the pricing chain they target. DIST mitigates the mark-up of the import price Phillips curve while FIIP affects the mark-up of the domestic producers' price Phillips curve and decreases the weight of import prices in the CPI. DIST has usually been advocated to be efficient in addressing the exchange rate pass-through puzzle (e.g. Corsetti et al., 2008) and FIIP to significantly improve the international synchronization of business cycles (e.g. Huang and Liu, 2007 or Burstein et al., 2008). Our systematic comparison brings the surprising conclusion that the allocation of roles should actually be reversed. Though DIST indeed mitigates the connection between the exchange rate and the consumption price, this occurs via an attenuation of the exchange rate/import price relationship, in opposition to empirical evidence on the ERPT disconnect (cf. Stylized fact 1). However, this mechanism is pretty efficient in generating cross-border real spillovers after country specific shocks. It strongly improves international real synchronization after shocks that move output and the relative price of currency in opposite directions and they are not much deteriorated, if at all, after demand-like shocks.

This reversal of the outcome with respect to the primary goal also holds for input trade, that is the inclusion of import price in the marginal cost of domestic producers with a market power and staggered prices. Consistent with the observed ERPT diconnect, it systematically reduces the link between consumption price and exchange rate in the short run without affecting the strong relationship between import price and exchange rate. For all the shocks considered, the mechanism increases the cross-border correlation between consumption prices. Under perfect complementarity, it is also efficient in improving the international synchronization of the real economic activity after country specific shocks to which the policy rate reacts countercyclically, while for any kind of shocks it improves the within country imports-exports interconnection. FIIP also provides a natural channel between imports and exports. Finally, in our view, the input trade mechanism provides a strong economic rationale for a potentially high home bias in households' preference even for the very open economies, with all the benefits in terms of exchange rate disconnect it may imply (cf. Wang, 2010).

The ultimate test would be to bring the model to the data and to check how a two-country estimated model endowed with the two channels discussed at length in this paper allows to indeed (i) improve the estimation of both the import and consumption price dynamics and (ii) increase the real and nominal cross-border synchronization of macro-variables. This is at the agenda of future research.

References

[1] Adolfson, M., Laseen, S. Linde, J. and Villani, M. (2008), "Evaluating an estimated New Keynesian small open economy model", *Journal of Economic Dynamics and Control* 32, 8, 2690-2721.

[2] Berman, N., Martin, P. and Mayer, T. (2012). "How do different exporters react to exchange rate changes?", *Quarterly Journal of Economics*, 127, 1, 437–492.

[3] Bils, M. and Klenow, P. (2004), "Some evidence on the importance of sticky prices", *Journal of Political Economy*, 112, 5, 937-985.

[4] Burlon, L., Notarpietro, A. and Pisani, M. (2018), Exchange rate pass-through into euro area inflation. An estimated structural model, Bank of italy WP n°1192.

[5] Burstein, A., Neves, J. and Rebelo, S. (2003), "Distribution costs and real exchange rate dynamics during exchange-rate-based stabilizations", *Journal of Monetary Economics*, 50, 6, 1189-1214.

[6] Burstein, A., Kurz, C. and Tesar, L. (2008), "Trade, production sharing, and the international transmission of business cycles", *Journal of Monetary Economics*, 55, 4, 775-795.

[7] Burstein, A. and Gopinath, G. (2014), "International prices and exchange rates", *Handbook of International Economics*, 4th ed., 4: 391-451, Elsevier.

[8] Calvo, G.A. (1983), "Staggered prices in a utility-maximizing framework", *Journal of Monetary Economics,* 12, 3, 383-398.

[9] Campa, J. and Goldberg, L. (2010), "The sensitivity of the CPI to exchange rates: distribution margins, imported inputs and trade exposure", *Review of Economics and Statistics*, 92, 2, 392–407.

[10] Christiano, L., Eichenbaum, M. and Evans, C. (2005), "Nominal rigidities and the dynamic effects of a shock to monetary policy", *Journal of Political Economy*, 113, 1, 1-45.

[11] Colavecchio, R. and Rubene, I. (2020), *Non-linear exchange rate pass-through to euroarea inflation: a local projection approach*, ECB WP n°2362.

[12] Corsetti, G. and Dedola, L. (2005), "A macroeconomic model of international price discrimination", *Journal of International Economics*, 67, 1, 129-155.

[13] Corsetti, G., Dedola, L. and Leduc, S. (2008), "High exchange-rate volatility and low pass-through", *Journal of Monetary Economics*, 55, 6, 1113-1128.

[14] Dedola, L. and Lombardo, G. (2013), "Financial frictions, financial integration and the international propagation of shocks", *Economic Policy,* 27, 70, 319-359.

[15] de Walque, G., Jeanfils, Ph., Lejeune, T., Rychalovska, Y. and Wouters, R. (2017), *An estimated two-country EA-US model with limited exchange rate pass-through*, NBB WP n°317.

[16] Erceg, C., Guerrierri, L. and Gust, C. (2006), "SIGMA: a new open economy model for policy analysis", *International Journal of Central Banking*, 2, 1, 1-50.

[17] Eyquem, A. and Kamber, G. (2014), "A note on the business cycle implications of trade in intermediate goods", *Macroeconomic Dynamics,* 18, 1172-1186.

[18] Feenstra, R.C. (1998), "Integration of trade and disintegration of production in the global economy", *Journal of Economic Perspectives*, 12, 31-50.

[19] Georgiadis, G., Gräb, J. and Khalil, M. (2019), *Global value chain participation and exchange rate pass-through*, ECB WP n°2327.

[20] Huang, K. and Liu, Z. (2001), "Productions chain and general equilibrium aggregate dynamics", *Journal of Monetary Economics*, 48, 437-462.

[21] Huang, K. and Liu, Z. (2007), "Business cycles with staggered prices and international trade in intermediate inputs", *Journal of Monetary Economics*, 54, 1271-1289.

[22] Jacob, P. and Uusküla, L. (2019), "Deep habits and exchage rate pass-through", *Journal of Economic Dynamics and Control*, 105, 67-89.

[23] Johnson, R. (2014), "Trade in intermediate inputs and business cycle comovement", *American Economic Journal: Macroeconomics*, American Economic Association, 6, 4, 39-83.

[24] Justiniano, A. and Preston, B. (2010), "Can structural small open-economy models account for the influence of foreign disturbances?," Journal of International Economics, 81, 1, 61-74.

[25] Kamber, G. and Thoenissen, C. (2013), "Financial exposure and the international transmission of financial shocks", *Journal of Money, Credit and Banking* 45, s2, 159-195.

[26] Kollman, R. (2013), "Global banks, financial shocks and international business cycles: evidence from an estimated model", *Journal of Money, Credit and Banking*, 45, s2, 159-195.

[27] Lane, Ph. and Stracca, L. (2018), "Can appreciation be expansionary? Evidence from the euro area", *Economic Policy*, 33, 1, 225-264.

[28] Obstfeld, M. and Rogoff, K. (1995), "Exchange rate dynamics redux", *Journal of Political Economy*, 103, 3, 624-660.

[29] Ortega, E., and Osbat, C. (editors) (2020), *Exchange rate pass-through in the euro area and EU countries,* ECB Occasional Paper n°241.

[30] Özyurt, S. (2016), *Has the exchange rate pass-through recently declined in the euro area?*, ECB WP n°1955.

[31] Schmitt-Grohe, S. and Uribe, M. (2001), "Stabilization policy and the costs of dollarization", *Journal of Money, Credit and Banking* 33, 2, 482-509.

[32] Shambaugh, J. (2008), "A new look at pass-through", *Journal of International Money and Finance*, 27, 560-591.

[33] Shi, K. and Xu, J. (2007), "Optimal monetary policy with vertical trade production and trade", *Review of International Economics*, 15 (3) (2007), pp. 514-537

[34] Shi, K. and Xu, J. (2010), "Intermediate goods trade and exchange rate pass-through", *Journal of Macroeconomics*, 32, 571-583.

[35] Smets, F., Tielens, J. and Van Hove, J. (2018), *Pipelines pressures and sectoral inflation dynamics*, NBB WP n°351.

[36] Smets, F. and Wouters, R. (2002), "Openness, imperfect exchange rate pass-through and monetary policy", *Journal of Monetary Economics* 49, 5, 947-981.

[37] Smets, F. and Wouters, R. (2007), "Shocks and frictions in US business cycles: A Bayesian DSGE approach", *American Economic Review* 97, 3, 586-606.

[38] Taylor, J. (1980), "Aggregate Dynamics and Staggered Contracts", *Journal of Political Economy*, 88, 1, 1-24.

[39] Wang, J. (2010), "Home bias, exchange rate disconnect, and optimal exchange rate policy", *Journal of International Money and Finance,* 29, 55-78.

[40] Yi, K.-M. (2003), "Can vertical specialization explain the growth of world trade?, *Journal of Political Economy*, 111, 1, 52-102.

Technical Appendix

Proof. of Propositions 2 and 3

The domestic producers' Phillips curves for the Home and Foreign markets are given by equations (17) to (18). The corresponding foreign producers' Phillips curves are obtained by symmetry by systematically switching on/off the "*" indicator. The log-linearized marginal cost is equal to

$$\begin{aligned} \hat{mc}_{h,t} &= \left(1-\frac{\rho_m\eta}{\eta-1}\right)\hat{A}_{h,t}+\frac{\rho_m\eta}{\eta-1}\hat{p}_{f,t} \\ \text{with } A_{h,t} &= \alpha\hat{r}^k_{h,t}+(1-\alpha)\,\hat{w}_{h,t}-\varepsilon^a_{h,t} \end{aligned}$$

Rewriting the inflations equations for the home domestic production and import in terms of price levels, we get

$$\begin{aligned} \hat{p}^r_{h,t}+\hat{p}_{c,t} &= \Gamma_{h,t}+\Psi_h\left[\left(1-\frac{\rho_m\eta}{\eta-1}\right)\hat{A}_{h,t}+\frac{\rho_m\eta}{\eta-1}\hat{p}^r_{f,t}\right] \quad , \\ \hat{p}^r_{f,t}+\hat{p}_{c,t} &= \Gamma_{f,t}+\Psi_f\frac{\eta-1-\delta}{\eta-1}\left\{\left[\left(1-\frac{\rho^*_m\eta^*}{\eta^*-1}\right)\hat{A}^*_{h,t}+\frac{\rho^*_m\eta^*}{\eta^*-1}\hat{p}^{*r}_{f,t}\right]+\hat{s}_t\right\}+\frac{\delta\Psi_f}{\eta-1}\hat{p}^r_{h,t} \quad , \end{aligned}$$

where

$$\begin{aligned} \Gamma_{h,t} &= \frac{\hat{p}_{h,t-1}+\beta\hat{p}_{h,t+1}}{1+\beta+\frac{(1-\xi)(1-\beta\xi)}{\xi}\cdot\frac{\eta-1-\delta}{\eta-1}}, \\ \Gamma_{f,t} &= \frac{\hat{p}_{f,t-1}+\beta^*\hat{p}_{f,t+1}}{1+\beta^*+\frac{(1-\xi^*_m)(1-\beta^*\xi^*_m)}{\xi^*_m}}, \\ \Psi_h &= \frac{(1-\xi)(1-\beta\xi)\frac{\eta-1-\delta}{\eta-1}}{(1-\xi)(1-\beta\xi)\frac{\eta-1-\delta}{\eta-1}+\xi(1+\beta)}, \\ \text{and} \quad \Psi_f &= \frac{(1-\xi^*_m)(1-\beta^*\xi^*_m)}{(1-\xi^*_m)(1-\beta^*\xi^*_m)+\xi^*_m(1+\beta^*)} \quad . \end{aligned}$$

Substituting for $\hat{p}^r_{h,t}$ into $\hat{p}^r_{f,t}$ (and for $\hat{p}^{r*}_{h,t}$ into $\hat{p}^{r*}_{f,t}$) first and for $\hat{p}^{r*}_{f,t}$ into $\hat{p}^r_{f,t}$ afterwards, one obtains

$$\hat{p}^r_{f,t}=\frac{\left(\bar{\Psi}^s_f-\bar{\Psi}^{pf*}_f\bar{\Psi}^{s*}_f\right)\hat{s}_t+\bar{\Psi}^{A*}_f\hat{A}^*_{h,t}+\bar{\Psi}^{pf*}_f\left(\bar{\Psi}^A_f\hat{A}_{h,t}+R^{p^*_f}_t\right)+R^{p_f}_t}{\left(1-\bar{\Psi}^{pf*}_f\bar{\Psi}^{pf}_f\right)} \quad ,$$

where

$$\begin{aligned} \bar{\Psi}^s_f &= \frac{\Psi_f}{1-\frac{\delta}{\eta-1}\Psi_h\frac{\rho_m\eta}{\eta-1}}\frac{\eta-1-\delta}{\eta-1} \quad , \\ \bar{\Psi}^A_f &= \bar{\Psi}^{s*}_f\left(1-\frac{\rho_m\eta}{\eta-1}\right), \\ \bar{\Psi}^{pf}_f &= \bar{\Psi}^{s*}_f\frac{\rho_m\eta}{\eta-1}, \\ R^{p_f}_t &= \frac{\Gamma_{t,f}}{1-\frac{\delta}{\eta-1}\Psi_h\frac{\rho_m\eta}{\eta-1}}+\frac{\Psi_f\left[\Gamma_h+\Psi_h\left(1-\frac{\rho_m\eta}{\eta-1}\right)\hat{A}_t-\hat{p}_{c,t}\right]}{1-\frac{\delta}{\eta-1}\Psi_h\frac{\rho_m\eta}{\eta-1}}\frac{\delta}{\eta-1}. \end{aligned}$$

The coefficient of the exchange rate is the structural ERPT:

$$ERPT^{MP} = \frac{\bar{\Psi}_f^s - \bar{\Psi}_f^{pf*}\bar{\Psi}_f^{s*}}{1 - \bar{\Psi}_f^{pf*}\bar{\Psi}_f^{pf}},$$

and

$$\begin{aligned} ERPT^{MP}\big|_{\rho_m=\rho_m^*=0} &= \Psi_f \frac{\eta - 1 - \delta}{\eta - 1}, \\ ERPT^{MP}\big|_{\delta=\delta^*=0} &= \Psi_f \frac{1 - \frac{\rho_m^* \eta^*}{\eta^* - 1}\Psi_f^*}{1 - \frac{\rho_m^* \eta^*}{\eta^* - 1}\frac{\rho_m \eta}{\eta - 1}\Psi_f^* \Psi_f}. \end{aligned}$$

■

Calibration of the two-country model

Table A1: Calibration of the two-country symmetric model (on euro area)

Big ratios		Monetary policy	
$\frac{\bar{c}}{\bar{y}}$	0.56	interest rate persistence (ρ_r)	0.9
$\frac{\bar{\imath}}{\bar{y}}$	0.20	reaction to inflation (ρ_π)	1.6
$\frac{\bar{m}}{\bar{y}}$	0.20	reaction to output gap (ρ_{yg})	0.1
		reaction to output gap variation ($\rho_{\Delta yg}$)	0.1
Households		**Firms**	
external habit	0.7	Cobb-Douglas capital share (α)	0.33
hh relative risk aversion	1.2	capital depreciation rate	0.025
inv. elast. of effort w.r.t. wage	2	inv. adjustment cost	4
Calvo prob. wage	0.75	demand price elasticity (η)	4.5
hh Armington trade elasticity (λ_H)	3	Calvo prob. dom. price (ξ)	0.75
foreign/dom. goods adjust. cost	4	Calvo prob. imp. price (ξ_m^*)	0.33
		firms' Armington trade elasticity (λ_m)	3 or 0
		foreign/dom. goods adjust. cost	4

NATIONAL BANK OF BELGIUM - WORKING PAPERS SERIES

The Working Papers are available on the website of the Bank: http://www.nbb.be.

334. “Exchange rate movements, firm-level exports and heterogeneity”, by A. Berthou and E. Dhyne, *Research series*, January 2018.
335 “Nonparametric identification of unobserved technological heterogeneity in production”, by L. Cherchye, T. Demuynck, B. De Rock and M. Verschelde, *Research series*, February 2018.
336 “Compositional changes in aggregate productivity in an era of globalisation and financial crisis”, by C. Fuss and A. Theodorakopoulos, *Research series*, February 2018.
337. “Decomposing firm-product appeal: How important is consumer taste?”, by B. Y. Aw, Y. Lee and H. Vandenbussche, *Research series*, March 2018.
338 “Sensitivity of credit risk stress test results: Modelling issues with an application to Belgium”, by P. Van Roy, S. Ferrari and C. Vespro, *Research series*, March 2018.
339. “Paul van Zeeland and the first decade of the US Federal Reserve System: The analysis from a European central banker who was a student of Kemmerer”, by I. Maes and R. Gomez Betancourt, *Research series*, March 2018.
340. “One way to the top: How services boost the demand for goods”, by A. Ariu, F. Mayneris and M. Parenti, *Research series*, March 2018.
341 “Alexandre Lamfalussy and the monetary policy debates among central bankers during the Great Inflation”, by I. Maes and P. Clement, *Research series*, April 2018.
342. “The economic importance of the Belgian ports: Flemish maritime ports, Liège port complex and the port of Brussels – Report 2016”, by F. Coppens, C. Mathys, J.-P. Merckx, P. Ringoot and M. Van Kerckhoven, *Document series*, April 2018.
343. “The unemployment impact of product and labour market regulation: Evidence from European countries”, by C. Piton, *Research series,* June 2018.
344. “Trade and domestic production networks”, by F. Tintelnot, A. Ken Kikkawa, M. Mogstad, E. Dhyne, *Research series*, September 2018.
345. “Review essay: Central banking through the centuries”, by I. Maes, *Research series,* October 2018.
346. “IT and productivity: A firm level analysis”, by E. Dhyne, J. Konings, J. Van den Bosch, S. Vanormelingen, *Research series*, October 2018.
347. “Identifying credit supply shocks with bank-firm data: methods and applications”, by H. Degryse, O. De Jonghe, S. Jakovljević, Klaas Mulier, Glenn Schepens, *Research series*, October 2018.
348. “Can inflation expectations in business or consumer surveys improve inflation forecasts?”, by R. Basselier, D. de Antonio Liedo, J. Jonckheere and G. Langenus, *Research series*, October 2018.
349. “Quantile-based inflation risk models”, by E. Ghysels, L. Iania and J. Striaukas, *Research series*, October 2018.
350. “International food commodity prices and missing (dis)inflation in the euro area”, by G. Peersman, *Research series*, October 2018.
351. “Pipeline pressures and sectoral inflation dynamics”, by F. Smets, J. Tielens and J. Van Hove, *Research series*, October 2018.
352. “Price updating in production networks”, by C. Duprez and G. Magerman, *Research series*, October 2018.
353. “Dominant currencies. How firms choose currency invoicing and why it matters”, by M. Amiti, O. Itskhoki and J. Konings, *Research series*, October 2018.
354. “Endogenous forward guidance”, by B. Chafwehé, R. Oikonomou, R. Priftis and L. Vogel, *Research series*, October 2018.
355. “Is euro area lowflation here to stay? Insights from a time-varying parameter model with survey data”, by A. Stevens and J. Wauters, *Research series*, October 2018.
356. “A price index with variable mark-ups and changing variety”, by T. Demuynck and M. Parenti, *Research series*, October 2018.
357. “Markup and price dynamics: Linking micro to macro”, by J. De Loecker, C. Fuss and J. Van Biesebroeck, *Research series*, October 2018.
358. “Productivity, wages and profits: Does firms’ position in the value chain matter?”, by B. Mahy, F. Rycx, G. Vermeylen and M. Volral, *Research series*, October 2018.
359. “Upstreamness, social upgrading and gender: Equal benefits for all?”, by N. Gagliardi, B. Mahy and F. Rycx, *Research series*, December 2018.
360. “A macro-financial analysis of the corporate bond market”, by H. Dewachter, L. Iania, W. Lemke and M. Lyrio, *Research series*, December 2018.
361. “Some borrowers are more equal than others: Bank funding shocks and credit reallocation”, by O. De Jonghe, H. Dewachter, K. Mulier, S. Ongena and G. Schepens, *Research series*, December 2018.

362. “The origins of firm heterogeneity: A production network approach”, by A. B. Bernard, E. Dhyne, G. Magerman, K. Manova and A. Moxnes, *Research series*, January 2019.
363. “Imperfect competition in firm-to-firm trade”, by A. Ken Kikkawa, G. Magerman and E. Dhyne, *Research series*, January 2019.
364. “Forward guidance with preferences over safe assets”, by A. Rannenberg, *Research series*, January 2019.
365. “The distinct effects of information technologies and communication technologies on the age-skill composition of labour demand”, by S. Blanas, *Research series*, January 2019.
366. “A survey of the long-term impact of Brexit on the UK and the EU27 economies”, by P. Bisciari, *Document series*, January 2019.
367. “A macroeconnomic model with heterogeneous and financially-constrained intermediaries”, by Th. Lejeune and R. Wouters, *Research series*, February 2019.
368. “The economic importance of the Belgian ports: Flemish maritime ports, Liège port complex and the port of Brussels – Report 2017”, by E. Gueli, P. Ringoot and M. Van Kerckhoven, *Document series*, March 2019.
369. “Does banks’ systemic importance affect their capital structure and balance sheet adjustment processes?”, by Y. Bakkar, O. De Jonghe and A. Tarazi, *Research series*, March 2019.
370 “A model for international spillovers to emerging markets”, by R. Houssa, J. Mohimont and C. Otrok, *Research series*, April 2019.
371. “Estimation methods for computing a branch’s total value added from incomplete annual accounting data”, S. Vansteelandt, F. Coppens, D. Reynders, M. Vackier and L. Van Belle, *Research series*, April 2019.
372. “Do SVARs with sign restrictions not identify unconventional monetary policy shocks?”, by J. Boeckx, M. Dossche, A. Galesi, B. Hofmann and G. Peersman, *Research series*, June 2019.
373. “Research and development activities in Belgium: A snapshot of past investment for the country’s future”, by S. Vennix, *Research series*, July 2019.
374. “State dependent fiscal multipliers with preferences over safe assets” by A. Rannenberg, *Research series*, July 2019.
375. “Inequality, the risk of secular stagnation and the increase in household debt”, by A. Rannenberg, *Research series*, August 2019.
376. “Welfare effects of business cycles and monetary policies in a small open emerging economy”, by J. Mohimont, *Research series*, October 2019.
377. "Learning about demand abroad from wholesalers: a B2B analysis", by W. Connell, E. Dhyne and H. Vandenbussche, *Research series*, November 2019.
378. “Measuring trade in value added with Firm-level Data, by R. Bems and A. K. Kikkawa, *Research series*, November 2019.
379. “Scrapping the entitlement to unemployment benefits for young labor market entrants: An effective way to get them to work?”, by B. Cockx, K. Declercq, M. Dejemeppe, L. Inga and B. Van der Linden, *Research series,* December 2019.
380. “The impact of Brexit uncertainties on international trade: Evidence from Belgium”, by E. E. Schmitz, *Research series*, December 2019.
381. “The heterogeneous employment outcomes of first- and second-generation immigrants in Belgium”, by C. Piton and F. Rycx, *Research series*, January 2020.
382. “A Dane in the making of European Monetary Union – A conversation with Niels Thygesen”, by I. Maes and S. Péters, *Research series*, May 2020.
383. “Multi-product exporters: Costs, prices and markups on foreign vs domestic markets”, by Catherine Fuss, *Research series*, June 2020.
384. “Economic importance of the Belgian maritime and inland ports – Report 2018”, by I. Rubbrecht and K. Burggraeve, *Document series*, July 2020.
385. “Service characteristics and the choice between exports and FDI: Evidence from Belgian firms”, by L. Sleuwaegen and P.M. Smith, *Research series*, July 2020.
386. “Low pass-through and high spillovers in NOEM: What does help and what does not”, by G. de Walque, T. Lejeune, A. Rannenberg and R. Wouters, *Research series*, July 2020.

National Bank of Belgium
Limited liability company
RLP Brussels – Company’s number: 0203.201.340
Registered office: boulevard de Berlaimont 14 – BE-1000 Brussels
www.nbb.be

Editor

Pierre Wunsch
Governor of the National Bank of Belgium

Layout: Analysis and Research Group
Cover: NBB CM – Prepress & Image

Published in July 2020