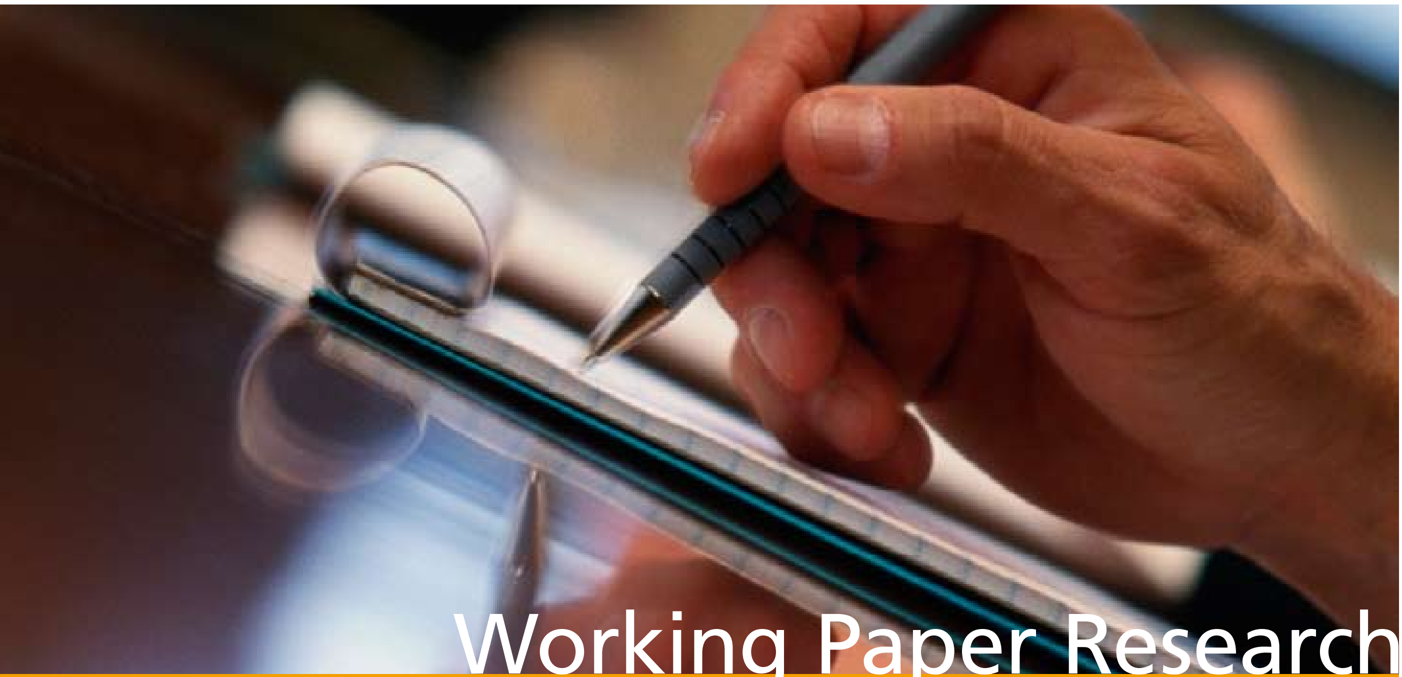
Imperfect exchange rate pass-through: the role of distribution services and variable demand elasticity



Working Paper Research

by Philippe Jeanfils

August 2008 No 135

NationalBank OF BELGIUM
Eurosystem

Working Paper Research series

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Philippe Jeanfils

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

Abstract

This paper examines which mechanisms are likely to dampen the price pressures in the wake of exchange rate movements. In addition to nominal frictions frequently used in sticky-price models, it jointly introduces two features that have hitherto been considered separately in the existing literature, i.e. a variable demand elasticity à la Kimball (1995) and distribution services in the form of non-traded goods as in Corsetti and Dedola (2005). The paper explores the respective role of each feature and assesses the quantitative importance of these theoretical explanations for the exchange rate pass-through to a broad range of prices as well as for the real exchange rate and for the trade balance. Segmentation of national markets through distribution services and imperfect competition with variable mark-ups are important for accounting for the observed stability of import prices "at the border". Hence, these mechanisms help to explain the observed stability of import prices in local currency with realistic durations of price contracts.

Keywords: exchange rate pass-through, general equilibrium.
JEL-code : F3 + F4

<u>Corresponding author</u>:

Philippe Jeanfils, NBB, Research Department, e-mail: philippe.jeanfils@nbb.be.

Acknowledgement: The author is very grateful to Raf Wouters and Gregory de Walque for their help and their fruitful and encouraging comments on this paper. Any remaining errors are of course the author's sole responsibility.

The views expressed in this paper are those of the author and do not necessarily reflect the views of the National Bank of Belgium.

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1 Introduction

Exchange rate variability is one of the most salient features of international macroeconomics. The managed exchange rate regimes adopted by many countries or the creation of the European Economic and Monetary Union have at least been partly motivated by a wish to dampen this variability. Large exchange rate fluctuations are nevertheless still observed: over the past ten years the exchange rates of the euro and the dollar have fluctuated a lot. However, changes have been reflected only moderately in domestic prices in the euro area and in the US, which have both enjoyed stable inflation - as most industrialised countries[1] -. These muted responses of macroeconomic variables have drawn attention, inter alia, to the degree of transmission of exchange rate movements along the pricing chain, i.e. exchange rate pass-through (ERPT). Empirical studies that try to estimate the ERPT show that it is far from perfect even for import prices "at the border" and in the long run. These findings have given rise to extensive research which provides different explanations as to why the ERPT might be incomplete. Along with price stickiness, real frictions are deemed necessary to account for incomplete ERPT. Two main real frictions will be considered here. Firstly, according to Corsetti and Dedola (2005), international price discrimination will arise because the price elasticity of demand in a market depends on local distribution costs which serve to segment national markets. Secondly, following Kimball (1995) an elasticity of demand that is increasing in the relative price will make the desired mark-up decreasing in the relative price which will result in smaller price increases than there would be if the elasticity of demand were constant.

This paper first aims at clearly identifying these different real channels and exploring their interactions in combination with nominal stickiness. Its second purpose is to assess the quantitative importance of these various assumptions for the exchange rate pass-trough to a broad range of prices, for the real exchange rate and for the trade balance by looking at impulse responses in a unified framework.

The remainder of the paper is organised as follows. The next section presents a brief overview of the empirical and theoretical literature. The third section specifies the two-country dynamic stochastic general equilibrium model that incorporates the ingredients presented above, focusing on the price formation mechanism. Section 4 presents the parameterisation of the model, while an analysis of impulse responses to an Uncovered Interest Rate

[1] This is also the case for emerging economies like Argentina, Brazil, Korea, etc. (see Burstein et al., 2005).

Parity shock evaluates the extent to which these nominal and real frictions have markedly different implications for the behaviour of open economies. Section 5 contains some concluding remarks. Finally, the appendix presents the key derivations of the paper.

2 Brief overview of the literature

Empirically, a number of common findings emerge from the numerous studies on the exchange rate pass-through. First, it is on average below one even in the long run and at disaggregated levels. Second, it varies across sectors (almost complete pass-trough for energy and commodities and quite low for manufactured goods[2]) and countries. The ERPT is lowest for the US where it has been estimated between 0.2 and 0.6 in the long run. As for the euro area, the long-run (*short-run*), i.e. one-year (*one-quarter*), exchange rate pass-through on extra-euro-area import prices ranges from a high 78 p.c. (*62 p.c.*) based on sectoral estimations for all euro area countries, (see Campa and Gonzalez-Minguez, 2006) to 70 p.c. (*20 p.c.*) based on VAR models, (Hahn, 2003, and Landolfo, 2007). Third, it is lower for consumer goods than for wholesale prices.

Recently, some empirical studies have observed a decline in the ERPT. The most striking evidence comes from the US. Marazzi et al. (2005), show a substantial decline in the ERPT to import prices from a value above 0.5 in the 1970's and 80's to a value close to 0.2 for the last decade. BIS (2005), Sekine (2005) and Ihrig, Marazzi, and Rothenberg (2006), have also detected declines for the G-7 countries, although not always significant, in the 1990-2004 period relative to the previous decades[3]. Yet this observation is disputed. Hellerstein, Daly and Marsh (2006) estimate that the ERPT to import prices in the US has only declined from 0.56 to 0.46 between the 1985-1994 and 1995-2005 periods, but this decline is not statistically significant[4]. In addition, this decline in import price pass-through does not appear to be a universal phenomenon. For some minor industrial countries like Australia and Sweden, for example, it seems that the pass-through to import prices has remained quite high[5]. A decline in import price pass-through suggests that

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[2]For the manufacturing sector in the euro area, Anderton (2003) obtains a long run ERPT in the range of 0.5 - 0.7 while Campa and Gonzalez-Minguez (2006) results are between 0.6 and 0.8.

[3]For example, in the latter study, the ERPT to import prices has declined on average from 0.7 to 0.5.

[4]They attribute the reduction observed in other studies to the inclusion of commodity prices in the regression analysis.

[5]Campa and Goldberg (2005) also report a reduction of ERPT since 1990 for 15 of the

exporters are increasingly absorbing exchange rate shocks into their domestic currency margins, rather than changing their foreign currency prices.

Although ERPT regression models can be biased by omitted variables and measurement errors, as shown by Corsetti et al. (2006), their main findings may give broad guidelines as to some desirable features of open economy macroeconomic models: there is (i) less than full pass-through to imported goods prices (at the dock) but (ii) more pass-through to imported goods prices than to final goods prices and (iii) possibly a decline in the pass-through.

These observations have posed a challenge to theoretical models. In response an extensive literature has provided different explanations as to why ERPT might be incomplete. Recent research has been conducted in the new open economy macroeconomic framework based on optimising behaviour[6]. The transmission to consumer prices has received much attention. One trend in this literature along the lines of Obstfeld and Rogoff (1995, 1998 and 2000) has assumed that prices are sticky in the producer's currency, PCP. Firms pre-set prices in their own currencies whether for sale to home or foreign markets. Here the response of import prices to the exchange rate is still one to one, but of course the impact on consumer prices depends on the import share or on some additional stickiness added by importers. Another trend (Betts and Devereux, 1996, 2000, for example) has assumed that import prices in each market are temporarily rigid in local currency. Under local currency pricing, LCP, which is an extreme case of Pricing-To-Market, there is no pass-through of exchange rates to import prices. Domestic firms set one price for sales in their own country and another price in foreign currency for sales abroad. As a result, import prices in each country are rigid in the consumer's currency and this nominal rigidity impedes the transmission of exchange rate changes to consumer prices in the short run.

Exogenous nominal frictions have then been introduced to build models with more realistic price dynamics. With price staggering, for example, prices of only a fraction of imported or exported goods can be adjusted in each period and can respond to exchange rate changes. This set-up implies that the pass-through coefficient is greater than zero in the short run for import prices and less than one for export prices. In order to improve their empirical performance, these models have also been supplemented by backward-looking indexation schemes and wage staggering (see for instance Smets and Wouters, 2002).

21 countries they studied, albeit insignificant in most cases. They ascribe this reduction to a composition effect in favour of manufactured goods for which ERPT is lower in aggregate imports rather than to a change in the relation between prices and exchange rate.

[6] For a very good survey, see Lane (2001).

Burstein et al. (2003) take a different direction from nominal frictions. They observe that the consumer price also includes non-traded marketing, distribution and retailing services and that these costs may be high. Exchange rate changes only affect the wholesale price, i.e. import price "at the border", which is only a small part of the final retail price of the distributed good. The argument is that the law of one price may hold for the good "at the border", as in PCP models, but does not hold at the level of the consumer price because it includes the price of non-traded domestic inputs for which the law of one price does not necessarily have to apply. In addition, distribution services have helped Burstein et al. (2007) to show why domestic inflation has not risen much even after large devaluations. They use the fact that the price adjustment in the non-traded sector is slow. In this context, they explain price sluggishness without turning to nominal frictions but rather by resorting to real rigidities, a flat marginal cost curve and a demand elasticity increasing in the firm's price relative to its competitors in the non-traded sector.

However, as shown above, imperfect exchange rate pass-through to import prices "at the border" is a well-documented phenomenon, i.e. the law of one price does not hold for a large number of tradables even at the border. To account for this incomplete pass-through both "at the border" and at the consumer level, Corsetti and Dedola (2005) develop a richer model of monopolistic competition among traded goods producers. In their model, international price discrimination arises because the price elasticity of demand in a market depends on local distribution costs which serve to segment national markets. Although firms set prices flexibly, the law of one price fails for traded goods because of different "perceived" price elasticities. Distribution costs are added to the price of imported goods and a change in the latter will affect the retail price only proportionally to the import content in the retail price. The demand reaction to this change will thus also be muted. Moreover, the exchange rate determines the relative weight of the traded good price in the retail price and thus influences the mark-ups.

In the spirit of Dornbusch (1987), incomplete pass-through may not primarily reflect price stickiness but arises from imperfectly competitive firms that find it optimal to adjust their mark-up and not only prices in response to exchange rate changes. Yet, in the absence of distribution costs, even if firms were given the ability to set different prices in different national market markets, there is no reason for them to do so, given that, when preferences are of the Constant Elasticity of Substitution type, they care only about their own costs. Bergin and Feenstra (2000, 2001) build general equilibrium models in which the pass-through is not perfect even with flexible prices. To circumvent the fact that under CES preferences strategic interaction with other firms is excluded, they instead introduce "translog" preferences. They use a model with staggered pricing and show that endogenous real exchange rate persistence can be increased by a variable demand elasticity, a low degree of openness or a large role for intermediate materials in production, but not to the extent actually observed in the data.

Other authors - e.g. Bouakez (2005), de Walque et al. (2005), Gust and Sheets (2006), Landry (2006), Sbordone (2008) - have applied recipes from the closed economy sticky-price literature[7] to open economy models. This research agenda introduces more general variable demand elasticity. More specifically, it considers the class of aggregator suggested by Kimball (1995) that yields an elasticity of demand that is increasing in the relative price. The fact that the elasticity of demand is increasing in the relative price means that the desired mark-up is decreasing in the relative price which results in smaller price increases than there would be if the elasticity of demand were constant. Hence, allowing for desired mark-up variations leads to additional price stickiness beyond that resulting from the exogenous nominal frictions. Consequently, it also helps to rationalise a large degree of nominal rigidity with a reasonable exogenous length of nominal contracts. In open economy models the relative price differential implies that a firm may face different demand elasticities at home and abroad.

This review indicates several features that might improve the open economy model:

1. Non-traded goods in the consumption basket: to get an ERPT lower at the consumer price level than at the import price level;

2. Staggered prices: to have persistence and an ERPT lower in the short run than in the long run;

3. Distribution sector: because it is important empirically and allows a lower ERPT to the retail price of import than to the price at the border and allows the latter to be less than one in the long run;

4. Endogenous variable demand elasticity: because of the need for a model in which prices and real exchange rate deviations last longer than the rigidity imposed by a realistic length of price contracts. These strategic mark-up variations are also motivated by the results from a market-specific study that analyses the source of inertia in the price of imports. In a study on the beer market in the US, Goldberg and Hellerstein

[7] e.g. Kimball (1995), Eichenbaum and Fisher (2007), Dotsey and King (2005), Coenen and Levin (2004), Levin et al. (2007).

(2007) attribute the source of local currency price stability for 54.1 p.c. to local non-traded costs, 33.7 p.c. to mark-up adjustment and 12.2 p.c. to price adjustment cost. These results shed light on the prevailing importance of real rigidities in explaining imperfect ERPT.

The introduction of variable demand elasticity offers a solution to deal with the documented decline in the ERPT. Distribution services can explain low pass-through but not the decrease in the ERPT. The period in which this possible decrease was observed is actually a period of increasing globalisation and there is no reason to believe that with more open markets, traded goods would require more domestic-cost-intensive services to be sold. Rather enhanced competition may have made producers more attentive to their relative price and thus less inclined to change their prices in response to exchange rate movements. The demand elasticity could also change with market conditions other than the relative price and these market conditions could evolve through time.

3 The model

The world economy consists of two countries of equal size denoted as Home, H, and Foreign, F. In each country, there is a continuum of infinitely-lived households and there are two sectors: one producing traded goods, the other producing non-traded goods. The traded sector produces a tradable good in a number of varieties indexed by $h \in [0,1]$ in the Home country and $f \in [0,1]$ in the Foreign country. The non-traded sector produces a continuum of differentiated non-traded goods, indexed by $n \in [0,1]$. Traded goods are the only goods exchanged internationally. Non-traded goods are either consumed or used to make tradable goods h and f available to domestic consumers. Variables located in the Foreign country are indexed by an asterisk '*'. Firms producing traded and non-traded goods are monopolistically competitive and produce one variety of goods only. These firms use differentiated domestic labour as inputs. For clarity, only the home-country variables and maximisation problems are described. The foreign country faces perfectly similar problems.

3.1 Domestic Households

In each country, there is a continuum of households indexed by $\tau \in [0,1]$, each one supplying a differentiated labour force. As in Smets and Wouters

(2003b), Home agent τ's intertemporal V utility is defined as

$$V_t(\tau) \equiv E_t \sum_{j=0}^{\infty} \beta^j \left(\frac{1}{1-\sigma_c} \left(C_{t+j}(\tau) - H_{t+j} \right) \right)^{1-\sigma_c} \cdot \exp\left(\frac{\sigma_c - 1}{1+\sigma_\ell} \ell_{t+j}(\tau)^{1+\sigma_\ell} \right) \tag{1}$$

where σ_c is the degree of relative risk aversion and σ_ℓ the elasticity of work effort with respect to the real wage. The external habit variable is assumed to be proportional to aggregate past consumption: $H_t = hC_{t-1}$.

Households' total income consists of labour income (net of taxes) and the dividend received from the imperfect competitive intermediate traded (h) and non-traded (n) firms in the Home economy. All domestic firms are entirely owned by domestic households and each domestic household holds an equal share in all firms.

The asset market structure in the model is standard in the literature. Home households hold their financial wealth in the form of domestic bonds $B_{H,t}$ and foreign bonds $B_{F,t}$ denominated in foreign currency. Bonds are one-period securities with a nominal gross return R_t and R_t^* respectively for the domestic and foreign bonds. As in Benigno (2001), to ensure a unique steady state equilibrium with a zero net foreign asset position, Home households are assumed to face a transaction cost when they take a position in the foreign bond market. This cost depends on the net foreign asset position of the Home economy[8].

Each household maximises its utility subject to the flow budget constraint:

$$\begin{aligned} \frac{B_{H,t}(\tau)}{R_t} + \frac{S_t B_{F,t}(\tau)}{R_t^* \Theta\left(S_t B_{F,t}/P_t\right)} \leq\ & B_{H,t-1}(\tau) + R_t^* S_t B_{F,t-1}(\tau) + w_t(\tau)\,\ell_t(\tau) \\ & + \int_0^1 div_t(h,\tau)\,dh + \int_0^1 div_t(n,\tau)\,dn \\ & - P_t C_t(\tau) \end{aligned} \tag{2}$$

This maximisation problem yields the following first-order conditions

$$\Xi_t = R_t \beta E_t \left[\Xi_{t+1} \frac{P_t}{P_{t+1}} \right] \tag{3}$$

$$\Xi_t = R_t^* \Theta\left(S_t B_{F,t}/P_t\right) \beta E_t \left[\Xi_{t+1} \frac{S_{t+1} P_t}{S_t P_{t+1}} \right] \tag{4}$$

[8]The cost function $\Theta()$ equals one when the net foreign asset position is at steady state level of zero. If they hold net foreign assets they receive a return lower than R^*, whereas if they are net debtors they have to pay more than foreign borrowers do.

where Ξ_t is the marginal utility of consumption and is given by

$$\Xi_t = (C_t - H_t)^{-\sigma_c} \cdot \exp\left(\frac{\sigma_c - 1}{1 + \sigma_\ell} \ell_t^{1+\sigma_\ell}\right) \tag{5}$$

and S is the nominal exchange rate, measured in units of Foreign currency per unit of Home currency[9]. Combining (3) and (4) yields the uncovered interest rate parity that determines the nominal exchange rate:

$$E_t\left[\frac{S_{t+1}}{S_t}\right] = \frac{R_t}{R_t^* \Theta\left(S_t B_{F,t}/P_t\right) \cdot \varepsilon_t^{uip}} \tag{6}$$

where an exogenous autoregressive risk premium shock ε_t^{uip} has been added to account for exogenous variations in international financial market conditions (see Schmitt-Grohé and Uribe, 2003).

3.2 Labour market

The treatment of the labour market and wage setting is the same as in Smets and Wouters (2003b), but made suitable for a two-sector economy.

Each worker acts as a monopolistic supplier of a differentiated type of labour input to all firms either in the traded or non-traded sector in the domestic economy (there is no labour mobility across countries). Each household sells differentiated labour services to a competitive firm, i.e. "labour packer" that packages them into a homogeneous input used for producing both tradable and non-tradable goods. Since the labour services are not perfect substitutes, households have some monopoly power and are therefore wage setters. Subject to a Calvo-type contract, they can only choose their wage optimally with a probability of $(1 - \xi_w)$. When they cannot reoptimise, their wage is indexed to both past consumer price inflation and to trend inflation, with respective shares γ_w and $(1 - \gamma_w)$. Optimising households choose their optimal nominal wage $\widetilde{w}_t(\tau)$ in order to maximise their intertemporal utility function (1) subject to the budget constraint (2) and the following labour demand curve:

$$\ell_t^j(\tau) = \left(\frac{w_t^j(\tau)}{W_t^j}\right)^{-\frac{1+\lambda_w}{\lambda_w}} L_t^j$$

where W_t^j is the price index for labour inputs in sector $j = H,\ N$.

[9] Thus an increase in S corresponds to a depreciation of the domestic currency.

The total labour supply of individual τ is $\ell(\tau)$. It is assumed that from the individual point of view, supplying labour to the traded or non-traded sector is equivalent (i.e. labour supply in the traded and non-traded sector are perfect substitutes). As shown in Erceg et al. (2000), the labour packer combines individual households' supply according to:

$$L_t = \left[\int_0^1 \ell_t^j (\tau)^{\frac{1}{1+\lambda_w}} \, d\tau \right]^{1+\lambda_w}$$

and the corresponding price index for labour inputs

$$W_t = \left[\int_0^1 w_t^j (\tau)^{-\frac{1}{\lambda_w}} \, d\tau \right]^{-\lambda_w}$$

where $j = H,\ N$. In order to keep the labour market structure symmetric between sectors, the elasticity of substitution between labour, $\frac{1+\lambda_w}{\lambda_w}$, is assumed to be the same in the traded and non-traded sectors. Optimising households will set their wage rate as a mark-up over the marginal rate of substitution between consumption and leisure:

$$\frac{\overline{W}_t}{P_t} = (1+\lambda_w) \frac{U'_{\ell,t}}{\Xi_t}$$

where U'_ℓ is the marginal disutility of labour which is equal across households and is given by

$$U'_{\ell,t} = \left(\frac{1}{1-\sigma_c} (C_t - hC_{t-1}) \right)^{1-\sigma_c} \cdot \exp\left(\frac{\sigma_c - 1}{1+\sigma_\ell} \ell_{t+j}^{1+\sigma_\ell} \right) (\sigma_c - 1)\, \ell_t \quad .$$

With the partial adjustment and indexation mechanisms described above, their optimisation problem yields to the first-order condition:

$$E_t \sum_{j=0}^{\infty} (\xi_w \beta)^j \frac{\Xi_{t+j} P_t}{\Xi_t P_{t+j}} \frac{\ell_{t+j}(\tau)}{\lambda_w} \left[(1+\lambda_w) \overline{W}_{t+j} - \left(\Pi_{k=0}^{j} \pi_{t+k-1}^{\gamma_w} \overline{\pi}^{(1-\gamma_w)} \right) \widetilde{w}_t(\tau) \right] = 0$$

and the aggregate wage equation is:

$$W_t = \left[(1-\xi_w) \widetilde{w}_t^{\frac{1}{\lambda_w}} + \xi_w \left(\pi_{t-1}^{\gamma_w} \overline{\pi}^{(1-\gamma_w)} W_{t-1} \right)^{\frac{1}{\lambda_w}} \right]^{\lambda_w}$$

3.3 Demand structure

Aggregate consumption[10], C is an index of home Non-traded C^N and composite Traded C^T goods

$$C_t = \left(\left(\frac{\Phi_1}{\Phi_1 + (\Phi_2 + \Phi_3)} \right)^{\frac{1}{\rho}} C_t^{N\frac{\rho-1}{\rho}} + \left(\frac{(\Phi_2 + \Phi_3)}{\Phi_1 + (\Phi_2 + \Phi_3)} \right)^{\frac{1}{\rho}} C_t^{T\frac{\rho-1}{\rho}} \right)^{\frac{\rho}{\rho-1}} \quad (7)$$

where ρ is the intratemporal elasticity of substitution between traded and non-traded goods and Φ_1 determines the agent's bias towards the non-tradable goods while Φ_2 will determine the bias towards domestic traded goods and Φ_3 the bias towards imported goods in the demand for the composite traded good. Households allocate aggregate consumption based on the demand functions:

$$C_t^N = \frac{\Phi_1}{\Phi_1 + (\Phi_2 + \Phi_3)} \left(\frac{P_t^N}{P_t} \right)^{-\rho} C_t$$

$$C_t^T = \frac{(\Phi_2 + \Phi_3)}{\Phi_1 + (\Phi_2 + \Phi_3)} \left(\frac{P_t^T}{P_t} \right)^{-\rho} C_t$$

The corresponding competitive price index is

$$P_t = \left[\left(\frac{\Phi_1}{\Phi_1 + (\Phi_2 + \Phi_3)} \right) \left(P_t^N \right)^{(1-\rho)} + \left(\frac{(\Phi_2 + \Phi_3)}{\Phi_1 + (\Phi_2 + \Phi_3)} \right) \left(P_t^T \right)^{(1-\rho)} \right]^{\frac{1}{(1-\rho)}} \quad (8)$$

The composite Traded goods are a combination of (intermediate) goods produced in the Home and in the Foreign economy. In addition, bringing traded goods to the final demand requires the use of domestic non-traded goods, called distribution services. This feature creates a wedge between the "wholesale" prices - i.e. the producer's price of traded goods or the price "at the border" for imports - and their "retail" prices. Thus the composite Traded goods result from the aggregation of home-Traded-and-Distributed goods, Y_H^{TD}, along with imported-and-Distributed Foreign goods, Y_F^{TD}, according to the following technology:

$$C_t^T = \left(\left(\frac{\Phi_2}{\Phi_2 + \Phi_3} \right)^{\frac{1}{\lambda}} Y_{H,t}^{TD\frac{\lambda-1}{\lambda}} + \left(\frac{\Phi_3}{\Phi_2 + \Phi_3} \right)^{\frac{1}{\lambda}} Y_{F,t}^{TD\frac{\lambda-1}{\lambda}} \right)^{\frac{\lambda}{\lambda-1}} \quad (9)$$

[10] In the absence of investment and government, consumption is the final domestic demand .

where λ is the intratemporal elasticity of substitution between home produced and imported traded intermediate goods.

The composite Traded goods aggregators are perfectly competitive and, in order to maximise their profits each period they follow the optimal allocation between home-traded and imported goods as given by:

$$Y_{H,t}^{TD} = \frac{\Phi_2}{\Phi_2 + \Phi_3} \left(\frac{P_{H,t}^{TD}}{P_t^T} \right)^{-\lambda} C_t^T \tag{10}$$

$$Y_{F,t}^{TD} = \frac{\Phi_3}{\Phi_2 + \Phi_3} \left(\frac{P_{F,t}^{TD}}{P_t^T} \right)^{-\lambda} C_t^T \tag{11}$$

The corresponding price index is

$$P_t^T = \left(\left(\frac{\Phi_2}{\Phi_2 + \Phi_3} \right) P_{H,t}^{TD^{1-\lambda}} + \left(\frac{\Phi_3}{\Phi_2 + \Phi_3} \right) P_{F,t}^{TD^{1-\lambda}} \right)^{\frac{1}{1-\lambda}} \tag{12}$$

where P_H^{TD} and P_F^{TD} are respectively the price of traded Home and Foreign goods once distributed (i.e. the retail price of traded goods).

3.3.1 Distribution sector

As in Burnstein Neves et al. (2003) and Corsetti and Dedola (2005), traded Home and imported Foreign goods varieties need to go through distribution channels before their use in the production of the final goods Y_H^{TD} and Y_F^{TD}. The perfectly competitive retailers which distribute the traded goods use the non-traded bundle as the only additional input in production of Y_H^{TD} and Y_F^{TD}. Moreover, these inputs are considered as perfect complements so that the quantity of "retail" imported goods and of "retail" home-traded goods are respectively given by

$$Y_{F,t}^{TD}(f) = Min \left(\frac{1}{1+\delta} Y_{F,t}^{T}(f), \frac{\delta}{1+\delta} Y_{F,t}^{N(d)} \right) \tag{13}$$

$$Y_{H,t}^{TD}(h) = Min \left(\frac{1}{1+\delta} Y_{H,t}^{T}(h), \frac{\delta}{1+\delta} Y_{H,t}^{N(d)} \right) \tag{14}$$

With this Leontief technology for distribution, one unit of distributed traded good is made up of $\frac{1}{1+\delta}$ unit of genuine traded good and $\frac{\delta}{1+\delta}$ unit of the non-traded bundle.

3.3.2 Homogenous goods assemblers

The homogenous goods Y_t^N, Y_{Ht}^T and Y_{Ft}^T are produced by perfectly competitive assemblers using a continuum of inputs $y_t^N(n)$, $y_{ht}^T(h)$, $y_{ft}^T(f)$ which are respectively intermediate domestic non-tradable[11] (N) and domestic (h) tradable (T) goods and imported (m) intermediate goods that are produced by the monopolist intermediate goods sectors. As in Kimball (1995), the processing technology is given for each final good by the implicit functions[12]

$$\begin{aligned} 1 &= \int_0^1 G\left(\frac{y_t^N(n)}{Y_t^N}\right) dn \\ 1 &= \int_0^1 G\left(\frac{y_{ht}^T(h)}{Y_{Ht}^T}\right) dh \\ 1 &= \int_0^1 G\left(\frac{y_{ft}^T(f)}{Y_{Ft}^T}\right) df \end{aligned}$$

Subject to this technology, each assembler minimises the cost of producing respectively Y_t^N , Y_{Ht}^T and Y_{Ft}^T taking the price of each of the intermediate goods $p_t^N(n)$, $p_{h,t}^{TD}(h)$ and $p_{f,t}^{TD}(f)$ as given. The solution to this problem implicitly defines the relative individual input demands for each intermediate good i, $i = n, h, f$, as a function of its relative price[13]:

$$y_t^N(n) = G'^{-1}\left(\frac{p_t^N(n)}{P_t^N}\cdot \mathcal{I}_t\right) Y_t^N \quad (15)$$

$$y_{ht}^T(h) = G'^{-1}\left(\frac{p_{ht}^{TD}(h)}{P_{Ht}^{TD}}\cdot \mathcal{I}_t\right) Y_{H,t}^T \quad (16)$$

$$y_{ft}^T(f) = G'^{-1}\left(\frac{p_{f,t}^{TD}(f)}{P_{F,t}^{TD}}\cdot \mathcal{I}_t\right) Y_{F,t}^T \quad (17)$$

3.4 Intermediate goods producers

[11] Non-tradables need not be indexed by "h" or "f" since they are produced and used in the same country.

[12] G is increasing and strictly concave with $G(1) = 1$. Since, a first-order approximation to the model will be used, as in Eichenbaum and Fisher (2004), there is no need to specify a functional form for G.

[13] With flexible prices, the producer price indexes of these three categories of intermediate goods would be defined as a weighted sum of prices over individual good ratios: $P_{ht}^N = \int_0^1 p_{ht}^N(n)\frac{y_{ht}^N(n)}{Y_t^N}dn$; $P_{ht}^{TD} = \int_0^1 p_{ht}^{TD}(h)\frac{y_{ht}^{TD}(h)}{Y_t^{TD}}dh$; $P_{ft}^{TD} = \int_0^1 p_{ft}^{TD}(f)\frac{y_{ft}^{TD}(f)}{Y_{ft}^{TD}}df$.

3.4.1 Factor demands and marginal costs

Intermediate goods firms producing either non-traded $y_t^N(n)$ or traded goods which can be sold at Home $y_{ht}^T(h)$ or in the Foreign economy $y_{h,t}^*(h)$ are acting in monopolistic sectors characterised by sticky prices. Each of them has a production function with labour as the only input:

$$\begin{aligned} y_t^N(n) &= c_t^N(n) + y_{h,t}^{N(d)}(n) + y_{f,t}^{N(d)}(n) \\ &= \varepsilon_t^{A^N} \cdot \left[\int_0^1 \ell_t^N(\tau)^{\frac{1}{1+\lambda_w}} d\tau \right]^{1+\lambda_w} = \varepsilon_t^{A^N} L_t^N(n) \\ y_{h,t}^T(h) + y_{h,t}^*(h) &= \varepsilon_t^{A^T} \cdot \left[\int_0^1 \ell_t^T(\tau)^{\frac{1}{1+\lambda_w}} d\tau \right]^{1+\lambda_w} = \varepsilon_t^{A^T} L_t^T(h) \end{aligned}$$

where the autoregressive productivity shocks $\varepsilon_t^{A^N}$ and $\varepsilon_t^{A^T}$ are sector-specific. Thus, the marginal costs differ across sectors only in the presence of the sector-specific productivity shocks.

In equilibrium, production in the non-traded sector meets demand coming from 3 sources: final consumption of non-traded goods, inputs in distribution services needed to bring home-traded goods and imports to the final demand. Production in the traded sector satisfies Home demand for tradables and exports:

$$Y_{ht}^N(n) = \int_0^1 y_t^N(n)\, dn = C_t^N(n) + Y_{H,t}^{N(d)}(n) + Y_{F,t}^{N(d)}(n) \tag{18}$$

$$Y_{ht}^T(h) = \int_0^1 y_{h,t}^T(h) + y_{h,t}^{T*}(h)\, dh \tag{19}$$

3.4.2 Price-setting behaviour

The prices of intermediate goods producers are determined according to Calvo mechanisms. Each firm receives an opportunity to reset its price with a probability of $(1-\omega)$. Prices that cannot be adjusted are index-linked to past inflation in their sector with a weight γ_p and to trend inflation with a weight $(1-\gamma_p)$. From the Home economy perspective, four prices are important: the prices set by home-traded goods firms on the Home market and on the Foreign market, i.e. the price of exports, the price set by Foreign-traded goods firms on the Home market, i.e. the price of imports, and finally the price set by Home non-traded firms. The formula for setting these prices is derived as follows:

Traded goods producers. Traded goods producers sell their products to the final goods assemblers and can charge different prices at home and abroad. Their demand on the domestic market given by (16) depends on the retail price of their goods. Let us assume the price of non-tradables is $p(n) = P^N$. Then, given the assumed complementarity between traded and non-traded goods in the distribution sector, the "retail" price of a domestic traded good distributed at Home is

$$p_{h,t+j}^{TD}(h) = \frac{1}{1+\delta}\widetilde{p}_{ht}^{T}(h) X_{t,j} + \frac{\delta}{1+\delta} P_{t+j}^{N} \tag{20}$$

And an analogue expression holds for the "retail" price of exports:

$$p_{h,t+j}^{TD*}(h) = \frac{1}{1+\delta^*}\widetilde{p}_{ht}^{T*}(h) X_{t,j}^{H*} + \frac{\delta^*}{1+\delta^*} P_{t+j}^{N*} \tag{21}$$

where:

$$\begin{aligned} X_{t,j} &= \left(\frac{P_{H,t+j-1}^{T}}{P_{H,t-1}^{T}}\right)^{\gamma} \overline{\pi}^{j\cdot(1-\gamma)} = \prod_{k=1}^{j}\left(\pi_{t+k-1}^{T}\right)^{\gamma}\overline{\pi}^{(1-\gamma)} \\ X_{t,j}^{H*} &= \left(\frac{P_{H,t+j-1}^{T*}}{P_{H,t-1}^{T*}}\right)^{\gamma} \overline{\pi^{*}}^{j\cdot(1-\gamma)} = \prod_{k=1}^{j}\left(\pi_{t+k-1}^{h*}\right)^{\gamma}\overline{\pi^{h*}}^{(1-\gamma)} \end{aligned} .$$

A representative firm in the sector thus sells its output on both the domestic, y_h^T, and foreign, y_h^{T*}, markets and chooses prices $\widetilde{p}_{ht}^{T}$ and $\widetilde{p}_{ht}^{*}$ to maximise its expected profit stream:

$$E_t \sum_{j=0}^{\infty} (\omega\beta)^j \frac{\Xi_{t+j} P_t}{\Xi_t P_{t+j}} \left[\begin{array}{c} \widetilde{p}_{ht}^{T}(h) X_{t,j} y_{h,t+j}^{T}(h) \\ +S_{t+j}\widetilde{p}_{ht}^{T*}(h) X_{t,j}^{H*} y_{h,t+j}^{T*}(h) \\ -MC_{t+j}^{T}\left(y_{h,t+j}^{T}(h) + y_{h,t+j}^{T*}(h)\right) \end{array} \right] \tag{22}$$

s.t.

$$\frac{y_{h,t+j}^{TD}(h)}{Y_{H,t+j}^{TD}} = G'^{-1}\left(\frac{p_{h,t+j}^{TD}(h)}{P_{H,t+j}^{TD}}\cdot \mathcal{I}_{t+j}\right) = G'^{-1}\left(\phi_{t+j}\right) = z_{t+j}$$

$$\frac{y_{h,t+j}^{TD*}(h)}{Y_{H,t+j}^{TD*}} = G'^{-1}\left(\frac{p_{h,t+j}^{TD*}(h)}{P_{H,t+j}^{TD*}}\cdot \mathcal{I}_{t+j}^{*}\right) = G'^{-1}\left(\phi_{t+j}^{*}\right) = z_{t+j}^{*}$$

where Ξ_t is the marginal utility of consumption and $\left[\frac{\beta^j \Xi_{t+j} P_t}{\Xi_t P_{t+j}}\right]$ is the nominal discount factor for households which are the final owners the firms. For an exported good the domestic firm earns $S_{t+j}\widetilde{p}_{ht}^{T*} X_{t,j}^{H*}$.

Since marginal costs are constant, the maximisation problems in the Home and in the Foreign market can be treated separately. Log-linearisation of the first-order conditions of the firm around the steady state yields the two optimal prices set by a Home traded good firm that re-optimises at date t:

1. *Export price.* This price is set in the foreign currency:

$$\left(\widehat{\widetilde{p}}_{h,t}^{T*}(h) - \widehat{P}_{H,t}^{T*}\right) = (1-\omega\beta)\left[\begin{array}{c} \left(1 - \frac{\delta^{*}+\epsilon^{T*}}{(\eta^{T*}-1+\epsilon^{T*})}\right)\left(\widehat{mc}_{t}^{T} - \widehat{rs}_{t} + \widehat{P}_{t}^{*}\right) \\ + \frac{\delta^{*}}{(\eta^{T*}-1+\epsilon^{T*})}\widehat{P}_{t}^{N*} \\ - \frac{\left(\eta^{T*}-1\right)}{(\eta^{T*}-1+\epsilon^{T*})}\widehat{P}_{H,t}^{T*} \end{array}\right] - \omega\beta\left(\gamma\widehat{\pi}_{H,t}^{T*} - \widehat{\pi}_{H,t+1}^{T*}\right) + \omega\beta\left(\widehat{\widetilde{p}}_{h,t+1}^{T*}(h) - \widehat{P}_{H,t+1}^{T*}\right) \quad (23)$$

2. *Home-traded goods price.* Symmetricaly, a similar expression to (23) holds for the optimal price of a home-traded good sold on the home market:

$$\left(\widehat{\widetilde{p}}_{h,t}^{T}(h) - \widehat{P}_{H,t}^{T}\right) = (1-\omega\beta)\left[\begin{array}{c} \left(1 - \frac{\delta+\epsilon^{T}}{(\eta^{T}-1+\epsilon^{T})}\right)\left(\widehat{mc}_{t}^{T} + \widehat{P}_{t}\right) \\ + \frac{\delta}{(\eta^{T}-1+\epsilon^{T})}\widehat{P}_{t}^{N} \\ - \frac{\left(\eta^{T}-1\right)}{(\eta^{T}-1+\epsilon^{T})}\widehat{P}_{H,t}^{T} \end{array}\right] - \omega\beta\left(\gamma\widehat{\pi}_{t}^{T} - \widehat{\pi}_{t+1}^{T}\right) + \omega\beta\left(\widehat{\widetilde{p}}_{h,t+1}^{T}(h) - \widehat{P}_{H,t+1}^{T}\right) \quad (24)$$

Optimal traded goods prices are thus dependent on three main variables:

- the real marginal cost in the traded sector expressed in the currency of the buyer, $\left(\widehat{mc}_{t}^{T} - \widehat{rs}_{t}\right)$ or $\widehat{mc}_{t}^{T}$;
- the price of non-traded goods in the destination market, $\widehat{P}_{t}^{N*}$ or $\widehat{P}_{t}^{N}$;
- the price of their competitors in their respective market, $\widehat{P}_{H,t}^{T*}$ or $\widehat{P}_{H,t}^{T}$.

A comparison of the optimal prices (23) and (24) makes clear that home monopolistic firms, that take into account the impact of distribution costs on the perceived demand elasticity and their relative prices which are different at home and abroad, find it optimal to charge different prices in the Home and in the Foreign economy.

Non-traded goods producers. A non-traded intermediate goods firm chooses a price $\widetilde{p}_t^N$ to maximise

$$E_t \sum_{j=0}^{\infty} (\omega\beta)^j \frac{\Xi_{t+j} P_t}{\Xi_t P_{t+j}} \left[\widetilde{p}_t^N(n) X_{t,j}^N - MC_{t+j}^N \right] y_{t+j}^N(n) \tag{25}$$

s.t.

$$\begin{aligned} \frac{y_{t+j}^N(n)}{Y_{t+j}^N} &= G'^{-1}\left(\frac{\widetilde{p}_t^N(n) X_{t,j}^N}{P_{t+j}^N} \cdot \mathcal{I}_{t+j}^N \right) \\ &= G'^{-1}\left(\phi_{t+j}^N\right) = z_{t+j}^N \quad . \end{aligned}$$

The solution to this problem gives the optimal price set by a monopolistic producer of non-traded goods as:

$$\begin{aligned} \left(\widehat{\widetilde{p}}_t^N(n) - \widehat{P}_t^N \right) &= (1-\omega\beta)\left[\frac{\eta^N - 1}{\eta^N - 1 + \epsilon^N} \widehat{mc}_t^N - \frac{\eta^N - 1}{\eta^N - 1 + \epsilon^N}\left(\widehat{P}_t^N - \widehat{P}_t \right) \right] \\ &\quad -\omega\beta\left(\gamma \widehat{\pi}_t^N - \widehat{\pi}_{t+1}^N \right) \\ &\quad +\omega\beta\left(\widehat{\widetilde{p}}_{t+1}^N(n) - \widehat{P}_{t+1}^N \right) \end{aligned} \tag{26}$$

Note that

$$\frac{\eta^N - 1}{\eta^N - 1 + \epsilon^N} = \frac{1}{1 + \epsilon^N \zeta^N} \equiv A$$

where ζ^N is the steady state net desired mark-up and this expression is thus the same as in Eichenbaum and Fisher (2004). In the CES case, $\epsilon^N = 0$ and $A = 1$ which generates a constant mark-up. Eq. (26) implies that the larger ϵ^N is the less sensitive the optimal price to marginal cost. This simple relation shows that one can replicate any given effect of marginal costs on prices by increasing ϵ^N and lowering ω, i.e. ϵ^N enables the degree of nominal rigidity to be reduced.

Imported goods. A foreign producer who sells a traded good on the home market, $y_{f,t}(f)$, behaves symmetrically to a home exporter so that the analogous relation to (23) is

$$\begin{aligned} \left(\widehat{\widetilde{p}}_{f,t}^T(f) - \widehat{P}_{F,t}^T \right) &= \frac{(1-\omega\beta)}{(\eta^T - 1 + \epsilon^T)} \left[\begin{array}{c} \left(1 - \frac{\delta + \epsilon^T}{(\eta^T - 1 + \epsilon^T)}\right)\left(\widehat{mc}_t^{T*} + \widehat{rs}_t + \widehat{P}_t \right) \\ + \frac{\delta}{(\eta^T - 1 + \epsilon^T)} \widehat{P}_t^N - \frac{(\eta^T - 1)}{(\eta^T - 1 + \epsilon^T)} \widehat{P}_{F,t}^T \end{array} \right] \\ &\quad -\omega\beta\left(\gamma \widehat{\pi}_t^F - \widehat{\pi}_{t+1}^F \right) + \omega\beta\left(\widehat{\widetilde{p}}_{f,t+1}^T(f) - \widehat{P}_{F,t+1}^T \right) \end{aligned} \tag{27}$$

3.5 Phillips curves

There are three equations describing inflation in the Home country: one for imported inflation, one for domestic inflation in the traded sector and another for inflation in the non-traded sector.

The price index for imports with Calvo-type contracts is determined by

$$
\begin{aligned}
1 &= (1-\omega)\frac{\widetilde{p}_{f,t}^{T}(f)}{P_{F,t}}G'^{-1}\left(\frac{\widetilde{p}_{f,t}^{T}(f)}{P_{F,t}^{T}}\cdot\mathcal{I}^{F}\right) \\
&\quad +\omega\left(\pi_{t-1}^{F}\right)^{\gamma}\overline{\pi}^{1-\gamma}\left(\pi_{t}^{F}\right)^{-1}G'^{-1}\left(\left(\pi_{t-1}^{F}\right)^{\gamma}\overline{\pi}^{1-\gamma}\left(\pi_{t}^{F}\right)^{-1}\mathcal{I}^{F}\right) \quad .
\end{aligned}
$$

After linearisation the wholesale import price index for foreign goods results in

$$
\left(\widehat{\widetilde{p}}_{ft}^{T}(f)-\widehat{P}_{F,t}^{T}\right)=\frac{\omega}{1-\omega}\left(\pi_{t}^{F}-\gamma\pi_{t-1}^{F}\right) \tag{28}
$$

Combining (27) and (28) yields the Phillips curve for imports at the border:

$$
\begin{aligned}
\widehat{\pi}_{t}^{F} &= \frac{(1-\omega)(1-\omega\beta)}{\omega(1+\beta\gamma)}\left(\begin{array}{c}\left(1-\frac{\delta+\epsilon^{T}}{(\eta^{T}-1+\epsilon^{T})}\right)\left(\widehat{mc}_{t}^{T*}+\widehat{rs}_{t}+\widehat{P}_{t}\right)\\ +\frac{\delta}{(\eta^{T}-1+\epsilon^{T})}\widehat{P}_{t}^{N}\\ -\frac{\left(\eta^{T}-1\right)}{(\eta^{T}-1+\epsilon^{T})}\widehat{P}_{F,t}^{T}\end{array}\right) \\
&\quad +\frac{\beta}{(1+\beta\gamma)}\widehat{\pi}_{t+1}^{F}+\frac{\gamma}{(1+\beta\gamma)}\widehat{\pi}_{t-1}^{F}
\end{aligned} \tag{29}
$$

Proceeding along the same lines for home traded goods one gets:

$$
\begin{aligned}
\widehat{\pi}_{t}^{T} &= \frac{(1-\omega)(1-\omega\beta)}{\omega(1+\beta\gamma)}\left(\begin{array}{c}\left(1-\frac{\delta+\epsilon^{T}}{(\eta^{T}-1+\epsilon^{T})}\right)\left(\widehat{mc}_{t}^{T}+\widehat{P}_{t}\right)\\ +\frac{\delta}{(\eta^{T}-1+\epsilon^{T})}\widehat{P}_{t}^{N}\\ -\frac{\left(\eta^{T}-1\right)}{(\eta^{T}-1+\epsilon^{T})}\widehat{P}_{H,t}^{T}\end{array}\right) \\
&\quad +\frac{\beta}{(1+\beta\gamma)}\widehat{\pi}_{t+1}^{T}+\frac{\gamma}{(1+\beta\gamma)}\widehat{\pi}_{t-1}^{T}
\end{aligned} \tag{30}
$$

And for non-traded goods one obtains the Phillips curve:

$$
\begin{aligned}
\widehat{\pi}_{t}^{N} &= \frac{(1-\omega)(1-\omega\beta)}{\omega(1+\beta\gamma)}\cdot\left[\frac{\eta^{N}-1}{\eta^{N}-1+\epsilon_{h}}\widehat{mc}_{t}^{N}-\frac{\eta^{N}-1}{\eta^{N}-1+\epsilon_{h}}\left(\widehat{P}_{t}^{N}-\widehat{P}_{t}\right)\right] \\
&\quad +\frac{\beta}{(1+\beta\gamma)}\widehat{\pi}_{t+1}^{N}+\frac{\gamma}{(1+\beta\gamma)}\widehat{\pi}_{t-1}^{N}
\end{aligned} \tag{31}
$$

The aggregate price index is

$$P_t = \left[\begin{array}{c} \frac{\Phi_1}{\Phi_1+\Phi_2+\Phi_3} \left(P_t^N\right)^{(1-\rho)} + \frac{\Phi_2}{\Phi_1+\Phi_2+\Phi_3} \left(P_{H,t}^{TD}\right)^{(1-\rho)} \\ + \frac{\Phi_3}{\Phi_1+\Phi_2+\Phi_3} \left(P_{F,t}^{TD}\right)^{(1-\rho)} \end{array} \right]^{\frac{1}{(1-\rho)}} \tag{32}$$

or in deviation from steady state

$$\widehat{P}_t = \frac{\Phi_1}{\Phi_1+\Phi_2+\Phi_3} \widehat{P}_t^N + \frac{\Phi_2}{\Phi_1+\Phi_2+\Phi_3} \widehat{P}_{H,t}^{TD} + \frac{\Phi_3}{\Phi_1+\Phi_2+\Phi_3} \widehat{P}_{F,t}^{TD} \quad .$$

And, in terms of inflation,

$$\widehat{\pi}_t = \frac{\Phi_1}{\Phi_1+\Phi_2+\Phi_3} \widehat{\pi}_t^N + \frac{\Phi_2}{\Phi_1+\Phi_2+\Phi_3} \widehat{\pi}_{H,t}^{TD} + \frac{\Phi_3}{\Phi_1+\Phi_2+\Phi_3} \widehat{\pi}_{F,t}^{TD} \tag{33}$$

or

$$\widehat{\pi}_t = \frac{\Phi_1 + (\Phi_2+\Phi_3)\frac{\delta}{1+\delta}}{\Phi_1+\Phi_2+\Phi_3} \widehat{\pi}_t^N + \frac{\Phi_2 \frac{1}{1+\delta}}{\Phi_1+\Phi_2+\Phi_3} \widehat{\pi}_{H,t}^T + \frac{\Phi_3 \frac{1}{1+\delta}}{\Phi_1+\Phi_2+\Phi_3} \widehat{\pi}_{F,t}^T \tag{34}$$

The total share of non-traded goods in the economy is the sum of non-traded goods that enter directly into the consumption basket, C^N, with weight $\frac{\Phi_1}{\Phi_1+\Phi_2+\Phi_3}$ and of non-traded goods used as distribution services used to bring home-traded and imported goods to consumers with weight $\frac{(\Phi_2+\Phi_3)\frac{\delta}{1+\delta}}{\Phi_1+\Phi_2+\Phi_3}$.

3.6 Monetary policy

To close the model, monetary policy is endogenous and takes the form of the following feedback rule

$$\widehat{R}_t = \varkappa \widehat{R}_{t-1} + (1-\varkappa)\left[r_\pi \left(\widehat{\pi}_t - \overline{\pi}\right) + r_Y \left(\widehat{Y}_t - \widehat{Y}_t^P\right)\right] + \varepsilon_t^R \tag{35}$$

The parameter $\varkappa$ gives the degree of interest rate smoothing and ε_t^R is a temporary iid interest rate shock that will be dubbed a monetary policy shock.

3.7 *Factors affecting the ERPT*

The pricing rule (23) illustrates the elements that affect the exchange rate pass-through. The strength of the link between optimal export prices (in foreign currency), marginal costs and exchange rate depends on the following four main factors:

1. *The timing of price adjustments.* In a Calvo setting, individual firms cannot control the frequency of price revisions and must therefore incorporate their inability to reset their prices in their pricing decisions. Less frequent price revisions, i.e. a high parameter ω lowers the pass-through. However, in the long run, when all prices have received the opportunity to adjust, this mechanism vanishes.

   In order to better understand the remaining factors it is useful to abstract from price-staggering and let ω be zero. Then (23) can be rewritten in absolute rather than relative prices as:

$$\widehat{\widetilde{p}}_{h,t}^{T*}(h) = \left(\widehat{MC}_t^T - \widehat{S}_t\right) \quad - \frac{\delta^*}{(\eta^{T*} - 1 + \epsilon^{T*})}\left[\left(\widehat{MC}_t^T - \widehat{S}_t\right) - \widehat{P}_t^{N*}\right] - \frac{\epsilon^{T*}}{(\eta^{T*} - 1 + \epsilon^{T*})}\left[\left(\widehat{MC}_t^T - \widehat{S}_t\right) - \widehat{P}_{H,t}^{T*}\right] \tag{36}$$

   If $\delta^* = \epsilon^{T*} = 0$ which corresponds to the standard model without distributive costs and with a constant demand elasticity, the last two terms fall, the mark-up is constant and the ERPT is perfect.

2. *The share of distribution services*, δ^*. The value of η^{T*} gives the percentage change in demand following a change in the "retail" price, i.e. the price that the final user has to pay. Consider now a 10 p.c. increase in the "wholesale" price, i.e. the price set by the traded goods producer. Given that traded goods to reach the final consumer need to be combined with non-tradables as distribution services, this increase in the wholesale price only leads to a $\frac{1}{(1+\delta^*)}10$ p.c. increase in the retail price according to its definition (21). With a demand elasticity of η^{T*}, the ensuing reduction in demand will be $\left[\frac{1}{(1+\delta^*)}\eta^{T*}\right] \cdot 10$ p.c.. Thus, the steady state "perceived" demand elasticity on the foreign market for tradable goods is related to the "true" elasticity as follows

$$\eta^{T*\text{"}p\text{"}} = \frac{1}{(1+\delta^*)}\eta^{T*}$$

   As a result of distributive trade, it is thus lower than the "true" foreign demand price elasticity η^{T*}. In other words, the higher the distribution margin, the lower the "perceived" or "effective" elasticity of demand. Distribution margins reduce the pass-through of costs and exchange rate to the wholesale price because firms in the tradable sector realise when setting their prices that, in addition to their mark-up, the "retail" price for their good has two cost components: their own price which is determined by their own costs and by the ERPT and the distribution costs required to sell their production on the domestic or the foreign markets. Provided that the EPRT is positive, the weight on their own price decreases when the home currency depreciates. Thus a depreciation is associated with a relatively low demand elasticity. The presence of distribution services makes the mark-up contingent on the exchange rate and on the marginal cost versus the price set in the non-traded sector.

3. *The curvature of the demand curve*, ϵ^{T*}. As in Eichenbaum and Fisher (2007) and de Walque et al. (2005), I define the curvature as the elasticity of the price elasticity of demand with respect to the relative price at steady state:

$$\epsilon^{T*} = \frac{\widetilde{p}_h^{T*}/P_H^{TD*}}{\eta_h^{*"p"}(z^*)} \frac{\partial \eta_h^{*"p"}(z^*)}{\partial \widetilde{p}_h^{T*}/P_H^{TD*}} \Bigg|_{z^*=1}$$

The curvature parameter of the "perceived" demand curve may be derived as

$$\epsilon^{T*} = 1 + \eta^{T*} \left(1 + \frac{G'''}{G''}\right)$$

which corresponds to Chari et al.'s (2000) result in the absence of distribution margins[14]. When $\epsilon^{T*} > 0$, the demand elasticity is an increasing function of a firm's price relative to its competitors. A higher value of ϵ^{T*} reduces the pass-through since, for any given rise in its price, the demand curve is more elastic which raises the cost of deviating from the average price. In other words, if firms do not want their price to deviate too far from their competitors' when they are allowed to fix their price, then the presence of even a small number of firms that see a fall in their relative price because they do not change their price dissuades the adjusting firms from making any major price changes and deviating from the average behaviour. Note that in the absence of any other shock to marginal costs, after depreciation of the exchange rate, costs expressed in local currency rise by the same amount for all firms in a sector, so if prices are flexible they will all rise by that amount and

[14] Coenen and Levin (2005) call this coefficient the relative slope of the demand elasticity around its steady state while Klenow and Willis (2005) call it the super-elasticity or the rate of change of the elasticity.

market shares and mark-ups remain constant. It is the combination of staggered price-setting with a variable demand elasticity that makes mark-ups variable. In a flexible price equilibrium, $\widehat{p_{ht}^{*}}(h) = \widehat{P_{H}^{*}} \;\; \forall h$, the curvature parameter cancels itself out in (36) and, in the absence of distribution, the desired mark-up would remain constant. The assumption that η decreases (increases) with the market share[15] (relative price) implies that each firm's mark-up of its price over marginal cost is an increasing function of that firm's market share within its sector. If the firm has a market share approaching one, it perceives only the sectoral elasticity of demand η and chooses a constant mark-up equal to $\frac{\eta}{\eta-1}$. Thus a variable demand elasticity breaks the link between prices and costs and raises the possibility that firms will not pass changes in cost one-for-one on to prices. Specifically, if some firms in a sector experience an increase in marginal cost relative to the other firms in the sector, these former firms will lose market share and hence cut their mark-up in equilibrium. As a result, the prices charged by these firms will rise by less than the rate of increase in their costs.

4. *The "true" elasticity of demand, η^{T*}.* In the abscence of real rigidities, $\epsilon^{T*} = \delta^{*} = 0$, the demand elasticity would have no effect on the pass-through. When one or both real rigidities is present the transitional dynamics do depend on the value of the demand elasticity: a higher elasticity increases the dynamic price response to both the marginal cost and the exchange rate. So, for a given degree of curvature and distribution services, the higher the price elasticity at steady state, the smaller the steady state mark-up and thus the lower the margin for a firm, deviating from the symmetric equilibrium, to absorb exchange rate and cost changes in its mark-up and thus the more closely its optimal price will follow cost and exchange rate movements.

In a model without distribution, Bergin and Feenstra (2001) obtain imperfect exchange rate pass-through with flexible prices because their translog expenditure function aggregates goods traded internationally along with non-traded goods. Foreign firms thus compete with local producers that sell non-traded goods and, to the extent that these competitors do not adjust their prices when the exchange rate moves, they refrain from adjusting their own price. However, as the number of traded goods increases, the ERPT also increases because firms will optimally follow what their competitors -who become more homogenous- are doing. Imperfect pass-through with flexible

[15] The demand elasticity is given by $\eta\left(z_{t+j}^{*}\right) = \frac{-G\prime\left(z_{t+j}^{*}\right)}{z_{t+j}^{*}G\prime\prime\left(z_{t+j}^{*}\right)}$

prices thus requires traded goods to be competing with non-traded ones in the same way as non-traded goods in the form of distribution services are needed in my model. Apart from making the choice of curvature parameter more flexible, the difference lies in the degree of substitution between traded and non-traded goods. In Bergin and Feenstra's framework, the elasticity of substitution among traded goods varieties is the same as the elasticity of substitution between traded and non-traded varieties. When non-traded goods are introduced as distribution services, traded and non-traded varieties are considered as complements, whereas the elasticity of substitution between varieties of a given category - traded or non-traded - of goods, is higher and may differ between categories.

Interaction between δ and ϵ: The combination of δ and ϵ is a novel feature of the model. According to Woodford (2003), pricing decisions are defined as strategic complements if an increase in the prices charged for other goods raises the firm's own optimal price. In my model the degree of 'strategic' complementarity in price-setting is dependent on two channels:

- The first one is related to the price charged by non-traded goods firms. As in the CES model of Corsetti-Dedola (2005) and Corsetti et al. (2006), strategic complementarity arises as a consequence of monopolistic competition and distribution services. An increase in the price of non-tradables induces a firm in the tradable sector to raise its price. This id clearly apparent if one sets $\epsilon = 0$ in (36) which then boils down to:

$$\widehat{p_{ht}^{*}}(i) = \left(\widehat{MC}_t - \widehat{S}_t\right) - \frac{\delta^*}{\eta^{T*} - 1}\left(\left(\widehat{MC}_t - \widehat{S}_t\right) - \widehat{P}_t^{N*}\right)$$

  which, in turn, is a log-linearised version of the expression obtained by Corsetti and Dedola (2005). Thus, an increase in the price of non-traded in the destination market raises the mark-up and the price set by a traded goods firm;

- The second channel is related to the average price of their competitors. There are variations in desired mark-ups associated with changes in a firm's price relative to its competitors. This is in line with models that use a Kimball aggregator or with the open economy model of Bergin and Feenstra (2001).

However, when one allows for $\epsilon^{T*} > 0$, the first channel is affected and producers of tradables will reduce their response to an increase in the price set in the non-traded sector, i.e. the elasticity of the optimal traded goods price to the price of non-traded goods decreases from $\frac{\delta^*}{\eta^{T*}-1}$ to $\frac{\delta^*}{\eta^{T*}-1+\epsilon^{T*}}$. This can be understood as follows. Given that the "retail" price of a traded good is made up of two components - on the one hand, there is the own marginal cost in the traded sector expressed in the currency of the buyer; and, on the other hand, there is the price set by the distribution sector -, firms in the traded sector seeing a rise in the price of non-traded goods have less room to pass their own cost increases on to prices since the variable elasticity rises as their relative prices rise. Obviously, by definition, a convex demand curve implies that the loss of market share is an increasing function of the size of the price change. In order to see to what extent larger price increases lead to larger losses of market share, I use a Taylor series expansion of the elasticity of demand around the steady state, as in Chary et al. (2000). The first-order Taylor series expansion of $\eta^*(z_i^*)$ around $z_i^* = 1$ is given by

$$\eta^*(z_i^*) \approx \eta^*(1) - \left[1 + \eta^*(1) + \eta^*(1)\frac{G'''}{G''}\right] \cdot (z_i^* - 1)$$

where $\epsilon^{T*} = 1 + \eta^{T*} + \eta^{T*}\frac{G'''}{G''}$.

Let us choose a curvature where a 1 p.c. increase in a firm's market share which follows from a decrease in its relative price leads to a decline in the elasticity of demand from 5 to 4.75 and an increase in the desired mark-up from 1.25 to 1.2667. This parameterisation gives a value of $\epsilon^{T*} = 25$ or $\eta^{T*}\frac{G'''}{G''} = 19$. To further assess the implied convexity, Chary et al. (2000) take a second-order Taylor expansion series of the demand function at steady state, which is given by

$$\begin{aligned} z^*(i) &= G'^{-1}\left(\frac{p_h^{T*}(i)}{P_H^{TD*}}G'(1)\right) \simeq \\ & 1 - \eta^{T*} \cdot \left(\frac{p_h^{T*}(i)}{P_H^{TD*}} - 1\right) - \frac{\eta^{T*}\left(\eta^{T*}\frac{G'''}{G''}\right)}{2} \cdot \left(\frac{p_h^{T*}(i)}{P_H^{TD*}} - 1\right)^2 \end{aligned}$$

For $\eta^{T*} = 5$ and $\epsilon^{T*} = 25$, a 1 p.c. increase in the relative price leads to a 5.6 p.c. decline in demand (as compared to 5 p.c. in the CES case), whereas a 2 p.c. increase more than doubled the effect as it leads to a 12.7 p.c. reduction (as compared to 10 p.c. in the CES case). Therefore, allowing the desired mark-up to depend increasingly on the firm's market share affects the exchange rate pass-through by making it dependent not only on the scale of the exchange rate change - the larger the depreciation, the lower the ERPT - but also on the size and sign of changes in the price of non-traded goods - the larger a positive change in the non-traded goods price, the larger the increase in the elasticity and the larger the reduction in the desired mark-up implying a lower ERPT.

3.8 *Slope of the Phillips curve and Identification*

Let us omit indexation and rewrite (30) as

$$\widehat{\pi}_t^T = \frac{\kappa_p}{(\eta^T - 1 + \epsilon^T)} \left(\begin{array}{c} \left(\eta^T - 1 - \delta\right) \widehat{mc}_t^T \\ +\delta \left(\widehat{P}_t^N - \widehat{P}_t \right) \\ -\left(\eta^T - 1\right) \left(\widehat{P}_{H,t}^T - \widehat{P}_t \right) \end{array} \right) + \beta \widehat{\pi}_{t+1}^T \tag{37}$$

Table 1 reports parameterisations that all imply a slope of the Phillips curve of 0.05. For a given elasticity of inflation to real marginal cost, the presence of a variable demand elasticity allows for more reasonable contract duration as emphasised in Woodford (2005): here it comes down from 4.6 to 2.2 quarters. Without a distribution sector, all the parameterisations are observationally equivalent in terms of inflation dynamics: the coefficients of the marginal cost and of the traded good price are the same whatever the choice of demand elasticity and curvature. In the presence of a distribution sector, both the weight on the price of non-traded goods and the weight on the price of traded goods vary with the steady-state demand elasticity. For example, assuming a steady-state mark-up of 25 p.c. and a curvature parameter, $\epsilon^T = 25$, where a 1 p.c. increase in relative price leads to a 5.5 p.c. decrease in relative demand, or assuming a lower steady-state mark-up of 11 p.c., i.e. a doubling of the demand elasticity, and choosing a curvature parameter such that a 1 p.c. increase in relative price also causes a doubling of the loss of market share - from 5.5 to 11 p.c. - leads to different coefficients for the aggregate price of non-traded and traded goods. This increase in demand elasticity in turn leads to a smaller reaction of inflation to both prices. However, for a given demand elasticity, these coefficients are the same for all the choices of curvature which makes identification of the individual parameters impossible. In this case, $\left(\eta^T - 1 - \delta\right)$ is independent of the curvature parameter and the elasticity of inflation to marginal cost, $\kappa_p \frac{\eta^T - 1 - \delta}{\eta^T - 1 + \epsilon^T}$ has been constrained to be 0.05 for all specifications. Thus, by construction, the ratio $\frac{\kappa_p}{\eta^T - 1 + \epsilon^T}$ which in combination with δ and η^T determines the sensitivity of inflation in the traded goods sector to the aggregate price of non-traded and traded goods is the same for all degrees of curvature once δ and η^T are kept fixed.

Table 1:
Combinations of parameters that yield the same Phillips curve slope

η^T	ϵ^T	δ	ω	κ_p	$\frac{\eta^T-1-\delta}{\eta^T-1+\epsilon^T}$	mc^T	P^N	P^T	duration
5	0	0	0.803	0.050	1	0.05	0	-0.05	4.6
5	0	2/3	0.787	0.060	0.83	0.05	0.010	-0.060	4.2
5	25	0	0.554	0.363	0.14	0.05	0	-0.05	2.2
5	25	2/3	0.525	0.436	0.11	0.05	0.010	-0.060	2.1
10	50.2	0	0.569	0.330	0.15	0.05	0	-0.05	2.3
10	50.2	2/3	0.559	0.351	0.14	0.05	0.004	-0.053	2.3

4 Parameterisation and functioning of the model

4.1 Parameterisation

This section is didactical and does not claim to be empirically realistic. An empirical validation of the model is left for further work. To make the explanation of the functioning of the model easier, I use a hypothetical symmetric two-country economy: Home and Foreign countries have the same size and parameter values. These parameters are summarised in table 2. A time period in the model is taken to be a quarter.

A low degree of relative risk aversion ($\sigma_c = 1$) and a high elasticity of labour supply ($\sigma_l = 0.25$) are chosen. The habit persistence parameter is fixed at 0.65. The subjective discount factor β equals 0.99. The parameter capturing the mark-up in wage setting is set at $\lambda_w = 0.25$.

The $\Phi's$ are endogenously chosen to ensure that, at steady-state, whatever the size of the distribution sector, the shares of non-traded, of home-traded and of imports in GDP remain respectively at 0.5, 0.25 and 0.25. There is thus no home bias in traded goods: $\frac{\Phi_2}{\Phi_2+\Phi_3} = 1/2$.

The elasticity of substitution between domestic and imported goods is set at 1.5 as in Chari et al.[16] (2002) and the elasticity of substitution between traded and non-traded goods is set at 1 as in many theoretical papers. This is above the value of 0.74 suggested by Mendoza (1995) but, here, these substitution possibilities only concern the traded versus non-traded as final goods while the overall substitution is quite lower given the fact that non-traded goods are complementary to traded ones in the form of distribution

[16] Bergin (2006) provides some evidence in favour of 1 and Lubik and Schorfheide (2005) estimate it at 0.4.

services.

I measure the distribution margin as a fraction $\frac{\delta}{1+\delta}$ of the retail price. Thus a 40 p.c. margin implies a value of 2/3 for the parameter δ as the remaining 60 p.c. of the retail price represents the wholesale price. In this model, the distribution sector is assumed to be competitive, so economic profits are zero and the distribution margin reflects the costs associated with providing distribution services. If the distribution sector is monopolistically competitive, the distribution margin also includes a mark-up component, as in Corsetti et al. (2007).

The variable demand elasticity is parameterised by ensuring that net mark-ups are equal to 0.25 across sectors at $z(i) = 1$. In the traded sector, the curvature parameter is chosen so that a 2 p.c. increase in price reduces demand by 11.9 p.c. as compared to 10 p.c. in the CES case. The probability of not changing prices is set at 0.525, implying an average duration of 2.1 quarters in the traded sector. In the non-traded sector, where nominal stickiness is larger according to Alvarez et al. (2005); the parameter is calculated to ensure that a weight on marginal cost in the inflation equation is close to 0.02 in both specifications with and without the distribution sector, a value commonly obtained in estimating the New Keynesian Phillips Curve. In combination with a curvature parameter set at 20, it equals 0.71 with the distribution sector and 0.63 without, corresponding to average durations of respectively 3.4 and 2.7 quarters. The indexation parameters are set at 0.5 for prices and 0.75 for wages.

Finally, in order to keep things as simple as possible, the monetary policy rule is assumed to reflect a pure inflation-targeting regime: the weight on output is zero and the weight on inflation is 1.5. The smoothing parameter equals 0.9.

Table 2: Parameter Values

Parameter	Description	Value
σ_c	degree of relative risk aversion	1
σ_ℓ	inverse of elasticity of labour supply	0.25
h	habit persistence	0.65
ξ_w	probability of not changing wages	0.8
γ_w	degree of indexation (wages)	0.75
$(1+\lambda_w)/\lambda_w$	elasticity of substitution (labour)	5
ρ	elasticity of substitution (traded vs non-traded)	1
λ	elasticity of substitution (home vs foreign)	1.5
β	discount factor	0.99
ω^T	probability of not changing prices (traded)	0.525
γ_p	degree of indexation (prices)	0.5
η^T	demand elasticity (traded)	5
ϵ^T	curvature	0; 25
δ	parameter governing the distribution margins	0; 2/3
ω^N	probability of not changing prices (non-traded)	0.71; 0.63
η^N	demand elasticity (non-traded)	$\eta^T/(1+\delta)$
ϵ^N	curvature (non-traded)	20
Φ_1	bias towards non-traded goods	endogenous
Φ_2	bias towards home-traded goods	endogenous
Φ_3	bias towards foreign goods	endogenous
$\varkappa$	degree of interest rate smoothing	0.9
r_π	coefficient on current inflation	1.5
r_Y	coefficient on output gap	0

4.2 Functioning of the model: Impulse responses to shocks

4.2.1 Uncovered Interest Rate Parity shock

This subsection compares impulse responses to a Uncovered Interest Rate Parity shock in four alternative specifications. First, I look at nominal rigidities only. Then, real rigidities are introduced separately. The impact of distribution costs is considered first. I consider the case with distributive trade, $\delta > 0$, but the demand function is still of the CES type by setting ϵ^T to zero in the demand for traded goods. Then, I look at a variant of the model with a variable demand elasticity, $\epsilon^T > 0$, but without distribution margins, $\delta = 0$. The proportion of traded and non-traded goods in the final consumption basket remains the same as with distributive trade but here all non-traded-goods are directly bought by consumers from non-traded producers. Finally, the model incorporates the real rigidities together. The full model is represented by a bold continuous line, the model without distribution services by stars '*', the CES variant by the combination of a thin line and points '·' and the model with only nominal stickiness by points '·'.

The size of the shock is scaled so that it triggers a 10 p.c. depreciation of the Home country exchange rate. It is assumed to be fairly persistent ($\rho = 0.9$) with its effect on the real exchange rate dying out only slowly over time. It affects both economies in a perfectly symmetric way. Because the model is symmetric, I concentrate on the results for the Home economy.

Firms' reactions: The first row of Figure 1 displays the optimal prices charged by Foreign price-adjusting firms on the Home market, called optimal import price (at the border), as well as the optimal wholesale prices charged by Home price-adjusting firms on Home and Foreign markets. The second row gives the respective price index accounting for firms which cannot adjust their price. All prices are expressed in the Home currency.

Of course, firms would prefer to change their price in response to the exchange rate or cost changes. However, in the Calvo framework they can only do so when they receive the price "signal". There is thus some gradual adjustment in all cases. In the presence of only nominal rigidities, both the domestic optimal traded good price and the optimal price of Home goods sold abroad increase slightly. On impact, the price that exporting firms are charging increases by some 2.4 p.c. This price increase then improves the Home-traded goods firms' margins. Given that the exchange rate appreciates by 10 p.c., this movement means that, once expressed in foreign currency, the price of domestic goods sold abroad falls by some 7.6 p.c., implying a high degree of pass-through.

When real rigidities are introduced, the optimal price of home-traded goods does not increase as much. On the contrary, the optimal export price increases even further: 3.6 p.c. when distribution is added, 7 when the demand elasticity is variable and 7.6 when both real factors are taken into account. The fact that domestic firms set two different prices at Home and abroad is a clear illustration of how market segmentation breaks the link between Home and Foreign demand and enables firms to price to market.

As shown by the optimal import price the degree of ERPT at the border strongly decreases when the variable elasticity is used. When the demand elasticity increases with the relative price, firms do not want to price differently than their competitors and lose (gain) market share by in(de)creasing their relative price. Therefore, with endogenous mark-ups, the shock translates into optimal price very gradually as re-optimised individual prices feed into the aggregate price and reduce the impact of price adjustments on market share. In contrast, when the elasticity of demand is constant firms which can re-optimise are less reluctant to raise (reduce) their price more on impact since they do not consider the impact of charging a higher (lower) price than their competitors.

When the distribution margin is set at 40 p.c. instead of zero, there is a smaller increase in both the optimal Home price of traded goods and in the optimal Home currency price of imports. As noted, an increase in δ lowers the "perceived" demand elasticity faced by traded goods producers and reduces the exchange rate pass-through to the wholesale price. Thus, exporters reduce their price in foreign currency by less than they would when δ is zero. As a result, once expressed in Home currency, export price further increases.

As expected, raising the demand elasticity, i.e. reducing δ, increases the exchange rate pass-through on optimal prices: Home producers' export price falls more in Foreign currency and Foreign producers' export price on the Home market increases more in Home currency. In addition, the difference is even greater under the CES specification. As explained above, when $\epsilon^T > 0$ producers of tradables reduce their response to an increase in the price set in the non-traded sector because they have less margin for increasing their price given that the variable elasticity rises as their relative prices rise. The effect of distributive trade is thus relatively smaller when the elasticity of demand is increasing with the relative price.

This being said, the most striking difference introduced by distribution trade is its impact on the retail price of import and on the expenditure-switching effects it generates.

Macroeconomic responses: On impact, the exchange rate overshoots its steady state. The first column of Figure 1-a illustrates how the exchange rate pass-through decreases along the pricing chain, i.e. it is highest for those firms that can re-optimise. Once aggregated with firms that do not reset their price, this yields the import price at the border, then the retail price of imports and finally, on the second panel of last row, the consumer price. Note that with no distribution margin both import prices are equal. In both CES cases, the maximum impact on import price "at the border" and on consumer price is reached after 3 quarters and 5 quarters respectively. When the elasticity is variable, there is much more smoothness and these delays increase substantially to 5 and 9 quarters respectively.

A rise in import price and a reduction in export price expressed in foreign currency induce a shift in demand towards domestic traded goods so that net exports improve substantially[17]. On the other hand, the current or expected deterioration in the terms of trade generates a negative wealth effect. Moreover with the simple monetary policy rule as in (35), the interest rate increases and consumption decreases. All in all, following the depreciation, Home output increases.

Although import prices "at the border" change the most with the CES aggregator, variations in net exports do not follow the same ranking. Expenditure-switching effects are in fact conditioned by the "retail" price of imports as in (11) where import demand depends on P_F^{TD}. Given that the "retail" price increases less in the presence of distributive trade, import volumes decrease less and their mirror image, export volumes, increases to a lesser extent. In addition, when distributive trade is added to the model, output in the non-traded sector falls even more sharply following the depreciation: there is a reduction in demand for non-traded goods used as retail services. There is also a limited increase in demand as a result of a reduction in non-traded output combined with a much lower net export improvement.

In the variants in which producers set prices while striving to maintain competitiveness against other producers, all price effects are smaller. In particular, the consumer price increases less and the response of monetary policy is less aggressive which results in a lower real interest rate. This induces a smaller reduction in consumption.

However, the striking difference in the output responses stems from the non-traded sector. In both scenarios with a distribution margin, there is a marked reduction of output in the non-traded sector accompanying the fall in imports. This reduction in distributive trade combined with a compression of domestic consumption keeps output almost at steady state despite the increase in exports. Without distributive trade, not only do net export improves more but also the decrease in the production of non-traded goods is very limited, which tends to boost domestic output.

Let us define the terms of trade as the ratio of the Home-currency price received on home goods exported abroad over the Home-currency price paid for goods imported from abroad. Under traditional Keynesian sticky-price models, the terms of trade decrease following domestic currency depreciation as the home-currency price paid for goods imported increases while the price received for exports does not change. Obstfeld and Rogoff (2000) provide empirical evidence of a negative comovement between the nominal exchange

[17] The chosen value for the elasticity of substitution (1.5) may be responsible for the scale of this result. A lower value as estimated by Bergin (2006) or Lubik and Schorfeide (2005) would reduce the net export boom.

rate and the terms of trade (a weaker currency is associated with a worsening of the terms of trade) and use it against the LCP hypothesis. Conversely, Bergin (2006) carries out a maximum likelihood estimate of a two-country model on US and G7 data and finds that a large proportion of firms behaves according to the assumption of Local Currency Pricing. In the current Pricing-To-Market environment, currency depreciation causes a temporary improvement of the terms of trade in all three cases where real rigidities come on top of the nominal price stickiness. Therefore, although the model generates a positive effect on the trade balance on impact, terms of trade movements contradict Obstfeld and Rogoff's argument.[18] However, after 3 quarters at most (when demand elasticity is variable), the model starts to show some deterioration in the terms of trade as the price paid for imported goods is above the price received for exported goods.

What drives RER movements? The real exchange rate fluctuates if Home and Foreign price levels are not perfectly correlated and an imperfect ERPT breaks this perfect correlation. Given that the movements in CPIs are larger under the CES specification, the real exchange rate depreciates somewhat less on impact than in the cases with a variable elasticity of demand.

Although the real exchange rate is by and large similar across the four models, the underlying factors explaining its movements differ considerably. In log deviations, the real exchange rate is: $\widehat{rs} = \widehat{s} + \widehat{P}^{*} - \widehat{P}$. Working in first differences and substituting Home inflation, π, by (34) and π^{*} by the similar expression for the foreign economy, after some further manipulations, one can decompose changes in the real exchange rate as follows[19]:

$$\begin{aligned}
\Delta\widehat{rs} \; = \; & \underset{(0.5)}{\frac{\Phi_1^{*} + \frac{\delta^{*}}{1+\delta^{*}}\left(\Phi_2^{*} + \Phi_3^{*}\right)}{\Phi_1^{*} + \left(\Phi_2^{*} + \Phi_3^{*}\right)}} \left(\widehat{\pi}^{N*} - \widehat{\pi}^{T*}\right) - \underset{(0.5)}{\frac{\Phi_1 + \frac{\delta}{1+\delta}\left(\Phi_2 + \Phi_3\right)}{\Phi_1 + \left(\Phi_2 + \Phi_3\right)}} \left(\widehat{\pi}^{N} - \widehat{\pi}^{T}\right) \\
& + \left(\underset{(0.5)}{\frac{\Phi_2}{\Phi_2 + \Phi_3}} - \underset{(0.5)}{\frac{\Phi_3^{*}}{\Phi_2^{*} + \Phi_3^{*}}} \right) \left(\widehat{\pi}_F^{T} - \widehat{\pi}_H^{T}\right) \\
& + \underset{(0.5)}{\frac{\Phi_2^{*}}{\Phi_2^{*} + \Phi_3^{*}}} \left(\widehat{\pi}_F^{T*} - \widehat{\pi}_F^{T} + \Delta\widehat{s}\right) + \underset{(0.5)}{\frac{\Phi_3^{*}}{\Phi_2^{*} + \Phi_3^{*}}} \left(\widehat{\pi}_H^{T*} - \widehat{\pi}_H^{T} + \Delta\widehat{s}\right)
\end{aligned} \tag{38}$$

[18] The addition of oil or commodities that are priced in a foreign currency could easily make the model conform more closely with Obstfeld and Rogoff views.

[19] The implied values for the parameters are given in brackets underneath.

Benigno and Thoenissen (2003) label these three sources of variation as:

$$\begin{aligned}\Delta rs &= Internal\ Exchange\ Rate \\ &+ Home\ bias \\ &+ Market\ Segmentation\end{aligned}$$

Note that, due to the presence of distribution services, the ratio of Home and Foreign import prices in Benigno and Thoenissen (2003) has been further decomposed into the contribution of the import price "at the border" and of the distribution services needed to bring imports to the final demand. These distribution services constitute an additional (indirect) channel through which changes in non-tradable prices affect the (internal) real exchange rate.

The Internal Exchange Rate channel allows the real exchange rate to deviate from PPP through the presence of non-traded goods in the consumption basket both as final consumption goods and as distribution services. The former is represented by the terms involving Φ_1^* and Φ_1 in the first row of (38), while $\frac{\delta^*}{1+\delta^*}$ and $\frac{\delta}{1+\delta}$ account for the latter. Thus, the higher the importance of the non-traded goods, the larger the real exchange rate sensitivity to changes in the relative price of non-tradables. As can be seen from the lower panel of Figure 1-c, this channel is responsible for twice as large a real exchange rate depreciation in the model with a constant demand elasticity than in the other two variants. In the CES cases, since traded goods firms do not aim to preserve their market share, they set prices more aggressively so that inflation in the Home-traded sector increases more and the relative price of non-traded goods thus decreases more.

The market segmentation channel highlights differences in prices in the same currency of traded goods *across* countries. In terms of level, market segmentation allows firms to price-to-market. If firms face different elasticities of demand in different markets as in the presence of distributive trade, this causes absolute PPP to fall. In the transitional dynamics depicted in the impulse responses, this channel affects the real exchange rate because there is incomplete pass-through from the exchange rate to prices so that the law of one price does not hold. As seen by comparing Figure 1-a and 1-c, the lower the exchange pass-through, the greater the contribution of the market segmentation channel. On the contrary, if the pass-through is perfect (which is the case, for instance, in the Producer Currency Pricing model), this channel would not contribute to the variability of the real exchange rate.

The home bias channel allows the real exchange rate to deviate from PPP through changes in the price of imported goods relative to those of the domestic tradable goods. The higher the degree of home bias, $\left(\frac{\Phi_2}{\Phi_2+\Phi_3} - \frac{\Phi_3^*}{\Phi_2^*+\Phi_3^*}\right)$, the more deviations in these terms of trade lead to deviations in the real exchange rate. However, in the simple symmetric two-country framework used here, this term cancels itself out.

Nominal trade balance adjustment: In the context of the ongoing debate on the reduction of large external imbalances, it is worth looking at the implications for the process of adjustment of imperfect ERPT. A Home currency depreciation has a moderate impact on the price of domestic goods in the world markets and on the ensuing expenditure-switching effects. However, what matters for long-run stability is the nominal trade balance and the adjustment can thus be achieved by changes either in import and export volumes or in the terms of trade.

In a static partial equilibrium framework with complete exchange rate pass-through, a depreciation of the Home currency leads to an improvement in the trade balance if the Marshall-Lerner condition is satisfied, i.e. if the sum of the import and export price elasticities is greater than one, $\mid \lambda \mid + \mid \lambda^* \mid > 1$, with the parameter λ being the elasticity of substitution between Home and Foreign goods as defined in (12).

In a model with no distribution sector, Gust and Sheets (2006) show that when trade price elasticities are near unity, a one p.c. depreciation of the exchange rate improves the trade balance by roughly one p.c. of the value of exports, regardless of the extent of the pass-through. In the present model with a distribution sector this is no longer the case.

Given that a Leontief technology has been assumed for the distribution services, the demand for imports moves proportionally to demand for imported and distributed goods, which in log-linearised form is

$$\widehat{Y}_F^{TD} = \widehat{Y}_F^T = -\lambda\left(\widehat{P}_F^{TD} - \widehat{P}^T\right) + \widehat{C}^T$$

The price of imported and distributed goods is given by

$$\widehat{P}_F^{TD} = \frac{1}{(1+\delta)}\widehat{P}_F^T + \frac{\delta}{(1+\delta)}\widehat{P}^N$$

where $\widehat{P}_F^T$ has been defined in (27). Recalling the definition of the real exchange rate, $\widehat{rs} = \widehat{s} + \widehat{p^*} - \widehat{p}$, the derivative of the "retail" import price with respect to the exchange rate is

$$\frac{\partial \widehat{P}_F^{TD}}{\partial \widehat{s}} = \frac{1}{(1+\delta)}\frac{\partial \widehat{P}_F^T}{\partial \widehat{s}} = \frac{1}{(1+\delta)}\left[\frac{\eta^T - 1 - \delta}{\eta^T - 1 + \epsilon^T}\right]$$

and the derivative of real import is

$$\frac{\partial \widehat{Y}_F^T}{\partial \widehat{s}} = \frac{-\lambda}{1+\delta}\left[\frac{\eta^T - 1 - \delta}{\eta^T - 1 + \epsilon^T}\right] \quad .$$

In log deviation, the trade balance as a percentage of the value of exports is

$$\begin{aligned}\widehat{\Upsilon} &= \widehat{P_x} + \widehat{Y}_H^{T*} - \widehat{P}_F^T - \widehat{Y}_F^T \\ &= \left(\widehat{s} + \widehat{P}_H^{T*} - \widehat{P}_F^T\right) + \left(\widehat{Y}_H^{T*} - \widehat{Y}_F^T\right) \quad .\end{aligned}$$

As expected, this relationship shows that the size and the sign of the adjustment depend on the response of the terms of trade and real net exports. The partial equilibrium effect of an exchange rate change on the nominal trade balance, Υ, is

$$\begin{aligned}\frac{\partial \widehat{\Upsilon}}{\partial \widehat{s}} &= \left(1 + \frac{\partial \widehat{P}_H^{T*}}{\partial \widehat{s}} - \frac{\partial \widehat{P}_F^T}{\partial \widehat{s}}\right) + \left(\frac{\partial \widehat{Y}_H^{T*}}{\partial \widehat{s}} - \frac{\partial \widehat{Y}_F^T}{\partial \widehat{s}}\right) \\ &= \left(1 - \frac{\eta^{T*} - 1 - \delta^*}{\eta^{T*} - 1 + \epsilon^{T*}} - \frac{\eta^T - 1 - \delta}{\eta^T - 1 + \epsilon^T}\right) \\ &\quad + \frac{\lambda^*}{1+\delta^*}\frac{\eta^{T*} - 1 - \delta^*}{\eta^{T*} - 1 + \epsilon^{T*}} + \frac{\lambda}{1+\delta}\frac{\eta^T - 1 - \delta}{\eta^T - 1 + \epsilon^T} \quad .\end{aligned}$$

Contrary to the case where $\delta = 0$, even if trade price elasticities are unity i.e. $\lambda^* = \lambda = 1$ the nominal adjustment still depends on the pass-through.

In the short run, if it is costly to reallocate demand between home and imported goods, the effective elasticity of substitution is lower than λ and the response of the trade balance to exchange rate changes will be subdued.

When both countries are symmetric and if $\lambda < 1+\delta$ (which seems the most realistic case), a one p.c. depreciation (increase in s) will improve the nominal trade balance by less than one p.c.. The improvement is weaker the greater the pass-through. In other words, for high curvature parameter values, the improvement in the nominal trade balance will be significant. Import prices do not change much in local currency terms so that the depreciating country experiences an improvement in its terms of trade, its import price hardly changes whereas its export price expressed in its own currency increases while real net exports rise slightly. On the contrary, if the pass-through to import prices is significant ($\frac{\eta^T-1-\delta}{\eta^T-1+\epsilon^T}$close to 1) and the home export price is therefore insensitive to the exchange rate, then a depreciation leads to a larger increase in real net exports. Complete pass-through enhances adjustment of real trade volume. For identical Home and Foreign countries, the above condition becomes

$$\frac{\partial \widehat{\Upsilon}}{\partial \widehat{s}} > 0 \Longleftrightarrow 1 + 2\left(\frac{\lambda}{1+\delta} - 1\right)\left(\frac{\eta^T - 1 - \delta}{\eta^T - 1 + \epsilon^T}\right) > 0 \quad .$$

An increase in δ reduces the real trade effect, exports increase less and imports decrease less in the variant with distribution services but, at the same time, together with the curvature parameter it reduces the exchange rate pass-through and improves the terms of trade. From this condition it is clear that the real trade effect dominates since it determines the sign of the second term in the inequality. This will be positive if and only if $\frac{\lambda}{1+\delta} > 1$ which, according to the chosen parameter values, only occurs when $\delta = 0$. The impulse responses conform with this partial equilibrium condition: the variant without distribution services leads to the largest improvement in the trade balance. Although the terms of trade are comparable to the results with distribution, the improvement in net exports is far larger. Net foreign assets holdings, confirms even more clearly how distributive trade reduces the improvement in a country's external position. With a distribution sector, the second term becomes negative and, in that case, the lower the pass-through, i.e. the higher ϵ^T, the less this second term is negative and thus the larger the improvement in the trade balance will be. However, there is some critical value for the trade elasticity. When $\lambda > 1 + \delta$, the second term is positive and a lower pass-through will reduce the improvement[20].

4.2.2 Increase in trade openness

Over the past decade, the world economy has experienced increasing globalisation. Firstly, this phenomenon has been accompanied by greater trade openness as measured by the share of imports in GDP. For instance, in the euro area, this share has grown from an average of 23 p.c. during the period 1980-1994 to 33 p.c. over the period 1995-2005[21]. Secondly, increased global competition has often been associated with a reduction in the level of inflation in the euro area and the US. One reason for this is that it may have made the demand curve facing domestic producers more elastic, since it has made more "substitute" goods available to domestic consumers. Thirdly, as emphasised by Marazzi and Sheets (2007), globalisation may have caused a reduction in the ERPT.

This section provides a quantitative assessment of the differences in the transmission channels of a 10 p.c. depreciation of the home currency following a UIRP shock as the trade openness of the economy varies. Beyond its direct impact on the level of inflation, globalisation may have altered the

[20] Note that this may make estimating the trade elasticity tricky.

[21] These figures include intra-euro area trade. For US and UK the import content of GDP increases respectively from 8 and 14 p.c. to 14 and 26 p.c respectively over the same sub-periods.

dynamics of inflation, namely the relation between inflation, marginal costs and exchange rate. With prices increasingly set in global markets, firms have less room to pass higher costs or exchange rate movements on to their prices and thus have to absorb more of these fluctuations in their profit margins. Empirical studies on the relationship between openness or globalisation and mark-ups are scarce but it might be that the effect of the increasing share of imports in total demand is strong. For example, using data from UK manufacturing firms, Bouhol et al (2006) estimate that a one percentage point increase in the share of imports in demand leads to a reduction of around one percentage point in the mark-up.

On the basis of these observations, globalisation is introduced in the model through a 10 percentage point increase in the share of imports in demand, i.e. from 25 p.c. to 35 p.c.. This increase in the share of imports is assumed to be accompanied by a 10 percentage point reduction in the steady-state mark-up. In other words, the demand elasticity at steady state rises from 5 to 7.7. Higher demand elasticity will lead to an increase in the ERPT to the import price and an increase in the Phillips curve slope. In addition, other things being equal, an increase in the share of imports in demand will raise the dependence of consumer prices on exchange rate movements. The empirical evidence reviewed in section 2 pointed instead a reduction in the ERPT at both the import price and the consumer price levels. If the demand elasticity also changes with market conditions other than the relative price, e.g. the degree of openness, it would play a crucial role in trying to reconcile these conflicting observations. Sbordone (2008) analyses channels through which an increase in trade openness affects the inflation process. Based on the intuition that the more goods are traded in a market, the more likely the demand is to fall in response to a small increases in prices, she makes the demand elasticity dependent on the number of goods traded (as a proxy for trade openness).

Figures 2-a and 2-b show the model responses to an increase in openness when the curvature is unchanged[22] and when the curvature is higher. In the latter case, it is such that a one p.c. decrease in relative demand leads to a 10 p.c. increase in demand elasticity.

Of course, in qualitative terms, the responses are in line with the responses of the variants presented in the previous section, although differences arise in the quantitative impacts. The currency depreciation raises import prices relative to domestic prices, and domestic producers respond to weaker com-

[22] The curvature is unchanged in the sense that a one percent decrease in relative demand still leads to a 5 p.c. increase in demand elasticity. Given that the demand elasticity is raised to 7.7, the curvature parameter, ϵ, equals 38.

petition from imports by increasing their desired mark-ups. In a more open economy the exchange rate pass-through to import prices is higher but the "relative" import price increases less. Given that more of their competitors are foreign, this weaker competition from imports is more keenly felt and domestic firms have more incentive to raise their mark-ups. Higher domestic prices, higher import prices and a bigger share of imports in consumption eventually lead to a bigger increase in consumer prices. Consumption declines to a larger extent in the more open economy as both prices and interest rates faced by consumers increase more. The improvement in net exports affects a larger part of output which thus expands further.

The higher degree of strategic complementarity first substantially reduces the ERPT to import prices. As expected when the curvature is higher, both foreign and domestic firms are more reluctant to raise their prices and the increase in mark-up is thus lower than it would be with an unchanged degree of curvature. Hence, the response of inflation is lower with a higher curvature. However, it remains higher than in a more closed economy. Consumption decreases less when the curvature is high. At the same time, the expenditure-switching effect causes net exports to move in the opposite direction to consumption. Overall, one expects output to increase to a greater extent in a more open economy since the share of imports in demand is by definition larger. Nevertheless, when a higher curvature mitigates the expenditure-switching effects, this is less the case.

In this short exercise on globalisation, variable desired mark-ups have proved important in reducing the ERPT to import prices. However, an implausibly high degree of curvature would be needed to account for the possible decline in the ERPT to the CPI. Other mechanisms than only those affecting price formation are probably at work: firms may be forced to do what they can to keep their costs from rising and, as advocated by Mishkin (2008), sound monetary policies aimed at maintaining price stability have also contributed to reduce the pass-through of exchange rate fluctuations to consumer prices.

5 Conclusions

This paper examines which mechanisms are likely to help dampen price pressures in the wake of exchange rate movements. In addition to nominal frictions frequently used in sticky-price models, it jointly introduces two features that have hitherto been considered separately in the existing literature, i.e. a variable demand elasticity and distribution services. The aggregator produces demand functions which are more elastic for firms that increase their prices than for firms whose relative price declines as a result of price stickiness. Such a variable elasticity leads to mark-up variations which are highly plausible in current open economies. As suggested by Gust et al. (2006), part of the decline in the exchange rate pass-through might be related to greater trade integration. In a global world, where it is increasingly important to maintain market share, firms are likely to prefer to adjust mark-ups rather than prices in response to a change in the exchange rate, disconnecting import prices from exchange rates. Further, the presence of a non-traded distribution sector reduces the effective price elasticity of import demand and generates market segmentation.

The model serves to examine the respective role of each feature. The paper shows that both separation of national markets through distribution services and imperfect competition with variable mark-ups leading to pricing-to-market are important for accounting for the observed stability of import prices in local currency at the border. Hence, when nominal frictions à la Calvo are present, the stability of import prices in local currency does not depend exclusively on price rigidities which results in more realistic durations of price contracts. Yet, when prices are flexible, the presence of non-traded goods is necessary to generate an imperfect pass-through.

To gauge the merits of the model, an empirical analysis should be conducted. Although, for the sake of simplicity, the model has left capital out, its introduction would make the model more suitable for estimation. This is left for further work.

6 Appendix

Derivation of Eq. (23)

The first-order condition for export price is

$$0 = E_t \sum_{j=0}^{\infty} (\omega\beta)^j \frac{\Xi_{t+j}}{\Xi_t} \left[S_{t+j} X_{t,j}^{H*} y_{h,t+j}^{T*}(h) + \left(S_{t+j} X_{t,j}^{H*} p_{ht}^{T*}(h) - MC_{t+j} \right) \frac{\partial y_{h,t+j}^{T*}(h)}{\partial \widetilde{p}_{ht}^{T*}(h)} \right] \tag{39}$$

and

$$\frac{\partial y_{h,t+j}^{T*}(i)}{\partial \widetilde{p}_{h}^{T*}(i)} = \frac{\partial y_{h,t+j}^{TD*}(i)}{\partial \widetilde{p}_{ht}^{T*}} = y_{h,t+j}^{T*}(i) \frac{\mathcal{I}_{t+j}^{*}}{z_{t+j}^{*} G''\left(z_{t+j}^{*}\right)} \frac{1}{P_{H,t+j}^{TD*}} \frac{X_{t,j}^{H*}}{1+\delta^{*}}$$

In steady state

$$S \cdot y_h^{T*}(h) + \left(S \widetilde{p}_h^{T*}(h) - MC \right) \cdot y_h^{T*}(h) \frac{\mathcal{I}^{*}}{z_{t+j}^{*} G''\left(z_{t+j}^{*}\right)} \frac{1}{P_H^{TD*}} \frac{1}{1+\delta^{*}} = 0$$

$$\frac{z_{t+j}^{*}G''\left(z_{t+j}^{*}\right)}{\mathcal{I}^{*}}\left(1+\delta^{*}\right)+\left(\frac{\widetilde{p}_{h}^{*}\left(h\right)}{P_{H}^{TD*}}-\frac{MC}{S\cdot P_{H}^{TD*}}\right)=0$$

$$\frac{z_{t+j}^{*}G''\left(z_{t+j}^{*}\right)}{\mathcal{I}^{*}}\left(1+\delta^{*}\right)+\left(\frac{\widetilde{p}_{h}^{T*}\left(h\right)}{P^{*}}\frac{P^{*}}{P_{H}^{TD*}}-\frac{MC}{\left(RS\frac{P}{P^{*}}\right)\cdot P^{*}}\frac{P^{*}}{P_{H}^{TD*}}\right)=0$$

$$\frac{z^{*}G''\left(z^{*}\right)}{\mathcal{I}^{*}}\left(1+\delta^{*}\right)+\left(\frac{\widetilde{p}_{h}^{T*}\left(h\right)}{P^{*}}\frac{P^{*}}{P_{H}^{TD*}}-\frac{mc}{RS}\frac{P^{*}}{P_{H}^{TD*}}\right)=0 \qquad (40)$$

where I made use of the fact that $RS=S\frac{P^{*}}{P}$ and $mc=\frac{MC}{P}$. Note that the real marginal cost is defined as the ratio of MC to the aggregate price in the Home economy and not to any (sectorial) price in the Foreign economy.

$$\Leftrightarrow \quad \frac{G''(1)}{G'(1)}\left(1+\delta^{*}\right)+\left(1-\frac{mc}{RS}\right)=0$$

$$\Leftrightarrow \quad \frac{mc}{RS}=1+\left(1+\delta^{*}\right)\frac{G''(1)}{G'(1)} \qquad (41)$$

The implied mark-up is equal to

$$mu^{*}(1) = \frac{1}{1+\left(1+\delta^{*}\right)\frac{G''(1)}{G'(1)}}=\frac{\frac{G'(1)}{G''(1)(1+\delta^{*})}}{\frac{G'(1)}{G''(1)(1+\delta^{*})}+1}$$

$$= \frac{\frac{-\eta^{T*}}{(1+\delta^{*})}}{\frac{-\eta^{T*}}{(1+\delta^{*})}+1}=\frac{\frac{\eta^{T*}}{(1+\delta^{*})}}{\frac{\eta^{T*}}{(1+\delta^{*})}-1} \qquad (42)$$

To continue, write first (39) as

$$E_{t}\sum_{j=0}^{\infty}\left(\omega\beta\right)^{j}\frac{\Xi_{t+j}}{\Xi_{t}}y_{h,t+j}^{T*}\left(h\right)\left[\begin{array}{c}\frac{\frac{S_{t+j}X_{t,j}^{H*}}{P_{t+j}}+\left(\frac{S_{t+j}\widetilde{p}_{ht}^{T*}(h)X_{t,j}^{H*}}{P_{t+j}}-mc_{t+j}^{T}\right)}{\frac{\mathcal{I}_{t+j}^{*}}{G'^{-1}\left(\phi_{t+j}^{*}\right)G''\left(z_{t+j}^{*}\right)}\frac{X_{t,j}^{H*}}{P_{H,t+j}^{TD*}}\frac{1}{1+\delta^{*}}\frac{\widetilde{p}_{h,t+j}^{TD*}(h)}{\widetilde{p}_{h,t+j}^{TD*}(h)}}\end{array}\right]=0 \quad .$$

Dividing by $X_{t,j}^{H*}$, multiplying by $\widetilde{p}_{h,t+j}^{TD*}\left(h\right)$ and using the fact that $\frac{\widetilde{p}_{h,t+j}^{TD*}(h)\mathcal{I}_{t+j}^{*}}{P_{H,t+j}^{TD*}}=\phi_{t+j}^{*}=G'\left(z_{t+j}^{*}\right)$

$$E_{t}\sum_{j=0}^{\infty}\left(\omega\beta\right)^{j}\frac{\Xi_{t+j}}{\Xi_{t}}y_{h,t+j}^{T*}\left(h\right)\left[\begin{array}{c}\left(1+\delta^{*}\right)\frac{\widetilde{p}_{h,t+j}^{TD*}(h)S_{t+j}}{P_{t+j}}+\\ \left(\frac{S_{t+j}\widetilde{p}_{ht}^{T*}(h)X_{t,j}^{H*}}{P_{t+j}}-mc_{t+j}^{T}\right)\frac{G'\left(z_{t+j}^{*}\right)}{G'^{-1}\left(\phi_{t+j}^{*}\right)G''\left(z_{t+j}^{*}\right)}\end{array}\right]=0$$

Then use the definition of the real exchange rate $\frac{RS}{P^{*}}=\frac{S}{P}$

$$E_{t}\sum_{j=0}^{\infty}\left(\omega\beta\right)^{j}\frac{\Xi_{t+j}}{\Xi_{t}}y_{h,t+j}^{T*}\left[\begin{array}{c}\left(1+\delta^{*}\right)\frac{\widetilde{p}_{h,t+j}^{TD*}(h)RS_{t+j}}{P_{t+j}^{*}}+\\ \left(\frac{RS_{t+j}\widetilde{p}_{h,t}^{T*}(h)X_{t,j}^{H*}}{P_{t+j}^{*}}-mc_{t+j}^{T}\right)\frac{G'\left(z_{t+j}^{*}\right)}{G'^{-1}\left(\phi_{t+j}^{*}\right)G''\left(z_{t+j}^{*}\right)}\end{array}\right]=0$$

$$
\begin{aligned}
& E_t \sum_{j=0}^{\infty} (\omega\beta)^j \frac{\Xi_{t+j}}{\Xi_t} y_{h,t+j}^{T*}(h) \frac{G'\left(z_{t+j}^*\right)}{G'^{-1}\left(\phi_{t+j}^*\right) G''\left(z_{t+j}^*\right)} \\
& \left[\begin{array}{c} (1+\delta^*) \frac{P_{H,t+j}^{TD*}}{P_{H,t+j}^{TD*}} \frac{\widetilde{p}_{h,t+j}^{TD*}(h) RS_{t+j}}{P_{t+j}^*} \frac{G'^{-1}\left(\phi_{t+j}^*\right) G''\left(z_{t+j}^*\right)}{G'\left(z_{t+j}^*\right)} + \\ \left(\frac{RS_{t+j}\widetilde{p}_{h,t}^{T*}(h) X_{t,j}^{H*}}{P_{t+j}^*} - mc_{t+j}^T \right) \end{array} \right] \\
= \; & 0 \quad .
\end{aligned}
$$

Then, using the fact that

$$
\frac{1}{G'\left(z_{t+j}^*\right)} \frac{\widetilde{p}_{h,t+j}^{TD*}(h)}{P_{H,t+j}^{TD*}} = \frac{1}{\mathcal{I}_{t+j}^*}
$$

and divide by RS to write the term between brackets as

$$
\left[\begin{array}{c} (1+\delta^*) \frac{P_{H,t+j}^{TD*}}{P_{t+j}^*} \frac{G'^{-1}\left(\phi_{t+j}^*\right) G''\left(z_{t+j}^*\right)}{\mathcal{I}_{t+j}^*} + \\ \frac{\widetilde{p}_{h,t}^{T*}(h) X_{t,j}^{H*}}{P_{t+j}^*} - \frac{mc_{t+j}^T}{RS_{t+j}} \end{array} \right] = 0 \quad .
$$

Multiply by $\frac{P_{t+j}^*}{P_{H,t+j}^{TD*}}$ to get

$$
\left[\begin{array}{c} (1+\delta^*) \frac{G'^{-1}\left(\phi_{t+j}^*\right) G''\left(z_{t+j}^*\right)}{\mathcal{I}_{t+j}^*} + \\ \left(\frac{\widetilde{p}_{ht}^{T*}(h)}{P_{H,t}^*} \right) \frac{X_{t,j}^{H*}}{X_{t,j}^{P^{F*}}} \frac{P_{H,t+j}^{T*}}{P_{H,t+j}^{TD*}} - \frac{P_{t+j}^*}{P_{H,t+j}^{TD*}} \frac{mc_{t+j}^T}{RS_{t+j}} \end{array} \right] = 0 \tag{43}
$$

where $X_{t,j}^{P^{F*}} = \frac{P_{t+j}^*}{P_t^*}$.

Now proceed to the linearisation of (43) around the steady state

$$
\begin{aligned}
& E_t \sum_{j=0}^{\infty} (\omega\beta)^j \frac{\Xi_{t+j}}{\Xi_t} \\
& \left[\begin{array}{c} \frac{(1+\delta^*)}{\mathcal{I}_{t+j}^*} \left(d\left(\phi_{t+j}^*\right) + \frac{G'''(1)}{G''(1)} d\left(\phi_{t+j}^*\right) \right) \\ + d\left(\frac{\widetilde{p}_{ht}^{T*}(h)}{P_{H,t}^{T*}} \right) + d\left(\frac{X_{t,j}^{H*}}{X_{t+j}^{P^{F*}}} \right) + d\left(\frac{P_{H,t+j}^{T*}}{P_{H,t+j}^{TD*}} \right) \\ - \frac{mc^T}{RS} \cdot d\left(\frac{P_{t+j}^*}{P_{H,t+j}^{TD*}} \right) - d\left(\frac{mc_{t+j}^T}{RS_{t+j}} \right) \end{array} \right] \\
= \; & 0
\end{aligned} \tag{44}
$$

where I used

$$
d\left(G'^{-1}\left(\phi_{t+j}^*\right)\right) = \frac{1}{G''\left(z^*\right)} d\left(\phi_{t+j}^*\right) \quad .
$$

Given that

$$
\begin{aligned}
d\left(\phi_{t+j}^{*}\right) &= d\left(\frac{\frac{1}{1+\delta^{*}}\widetilde{p}_{ht}^{T*}\left(h\right)X_{t,j}^{H*}+\frac{\delta^{*}}{1+\delta^{*}}P_{t+j}^{N*}}{P_{H,t+j}^{TD*}}\cdot\mathcal{I}_{t+j}^{*}\right) \\
&= \mathcal{I}^{*}\left[\begin{array}{c}\frac{1}{1+\delta^{*}}d\left(\frac{\widetilde{p}_{ht}^{T*}(h)}{P_{H,t}^{T*}}\right)+\frac{1}{1+\delta^{*}}d\left(\frac{X_{t,j}^{H*}}{X_{t,j}^{PF*}}\right)+\frac{1}{1+\delta^{*}}d\left(\frac{P_{H,t+j}^{T*}}{P_{H,t+j}^{TD*}}\right)\\ +\frac{\delta^{*}}{1+\delta^{*}}d\left(\frac{P_{ft+j}^{N*}}{P_{H,t+j}^{TD*}}\right)\end{array}\right],
\end{aligned}
$$

one can rewrite (44) as follows

$$
\begin{aligned}
&E_t\sum_{j=0}^{\infty}\left(\omega\beta\right)^{j}\frac{\Xi_{t+j}}{\Xi_t} \\
&\left[\begin{array}{c}\left(2+\frac{G'''(1)}{G''(1)}\right)d\left(\frac{\widetilde{p}_{h,t}^{*}(i)}{P_t^{*}}\right)+\left(2+\frac{G'''(1)}{G''(1)}\right)d\left(\frac{X_{t,j}^{H*}}{X_{t+j}^{PF*}}\right)\\ +\left(2+\frac{G'''(1)}{G''(1)}\right)d\left(\frac{P_{H,t+j}^{*}}{P_{H,t+j}^{TD*}}\right)\\ +\delta^{*}\left(1+\frac{G'''(1)}{G''(1)}\right)d\left(\frac{P_{t+j}^{N*}}{P_{t+j}^{*}}\right)\\ -\left(1+\left(1+\delta^{*}\right)\frac{G''(1)}{G'(1)}\right)d\left(\frac{P_{t+j}^{*}}{P_{H,t+j}^{TD*}}\right)-d\left(\frac{mc_{t+j}^{T}}{RS_{t+j}}\right)\end{array}\right] \\
&= 0
\end{aligned}
$$

minus the same expression in t+1 multiplied by $(\omega\beta)$ gives the optimal price for a producer that can reset its price as:

$$
\begin{aligned}
\left(\widehat{\widetilde{p}}_{h,t}^{T*}\left(h\right)-\widehat{P}_{H,t}^{T*}\right) &= \left(1-\omega\beta\right)\left[\begin{array}{c}\frac{\left(1+(1+\delta^{*})\frac{G''(1)}{G'(1)}\right)}{\left(2+\frac{G'''(1)}{G''(1)}\right)}\left(\widehat{mc}_t^{T}-\widehat{rs}_t\right)\\ -\delta^{*}\frac{\left(1+\frac{G'''(1)}{G''(1)}\right)}{\left(2+\frac{G'''(1)}{G''(1)}\right)}\left(\widehat{P}_t^{N*}-\widehat{P}_{H,t}^{TD*}\right)\\ +\frac{\left(1+(1+\delta^{*})\frac{G''(1)}{G'(1)}\right)}{\left(2+\frac{G'''(1)}{G''(1)}\right)}\left(\widehat{P}_t^{*}-\widehat{P}_{H,t}^{TD*}\right)\\ -\left(\widehat{P}_{Ht}^{T*}-\widehat{P}_{H,t}^{TD*}\right)\end{array}\right] \\
&\quad -\omega\beta\left(\gamma\widehat{\pi}_{H,t}^{T*}-\widehat{\pi}_{H,t+1}^{T*}\right)+\omega\beta\left(\widehat{\widetilde{p}}_{h,t+1}^{T*}\left(h\right)-\widehat{P}_{H,t+1}^{T*}\right)
\end{aligned}
\tag{45}
$$

As in Eichenbaum and Fisher (2004) and de Walque et al. (2005), the curvature is defined as the elasticity of the price elasticity of demand with respect to the relative price at steady state:

$$
\epsilon_h^{*}=\frac{\widetilde{p}_h^{T*}/P_H^{TD*}}{\eta_h^{T*}\left(z^{*}\right)}\frac{\partial\eta_h^{T*}\left(z^{*}\right)}{\partial\widetilde{p}_h^{T*}/P_H^{TD*}}\bigg|_{z^{*}=1}=\epsilon_h^{*}=1+\eta^{T*}\left(1+\frac{G'''}{G''}\right).
$$

Using this expression to eliminate the terms involving G yields

$$\frac{\left(1+(1+\delta^*)\frac{G''(1)}{G'(1)}\right)}{\left(2+\frac{G'''(1)}{G''(1)}\right)} = \frac{\eta^{T*}-1-\delta^*}{\eta^{T*}-1+\epsilon^{T*}}$$

$$-\delta^*\frac{\left(1+\frac{G'''(1)}{G''(1)}\right)}{\left(2+\frac{G'''(1)}{G''(1)}\right)} = -\delta^*\frac{\epsilon^{T*}-1}{\eta^{T*}-1+\epsilon^{T*}}$$

which enables (45) to be written in terms of the model parameters as in (23).

References

[1] Alvarez L., E. Dhyne, M. Hoeberichts, C. Kwapil, H. Le Bihan, P. Lünneman, F. Martins, R. Sabbatini, H. Stahl, P. Vermeulen and J. Vilmunen (2005), "Sticky Prices in the Euro Area: A Summary of New Micro Evidence", European Central Bank Working Paper, 563.

[2] Bank for International Settlements (2005), Annual Report No 75, June.

[3] Betts C. and M. Devereux (1996), "The Exchange Rate in a Model of Pricing-to-Market", European Economic Review, 40, 1007-1021.

[4] Betts C. and M. Devereux (2000), "Exchange Rate Dynamics in a Model of Pricing-to-Market", Journal of International Economics, 50, 215-244.

[5] Benigno G. and C. Thoenissen (2003), "Equilibrium exchange rates and supply-side performance", The Economic Journal, 113, 103-124.

[6] Benigno P. (2001), "Price stability with imperfect financial integration", CEPR Discussion Paper 2854.

[7] Bergin, P. (2006), "How Well Can the New Open Economy Macroeconomics Explain the Exchange Rate and Current Account?", Journal of International Money and Finance, 5 (5), 675-701.

[8] Bergin P. and R. Feenstra (2001), "Pricing-to-market, staggered contracts, and real exchange rate persistence", Journal of International Economics, 54, 333-359.

[9] Bergin P. and R. Feenstra (2000), "Staggered price setting, translog preferences, and endogenous persistence", Journal of Monetary Economics, 45, 657-680.

[10] Bils M. and P. Klenow (2004), "Some Evidence on the Importance of Sticky Prices", Journal of Political Economy, 112(5), 947–985.

[11] Bouakez H. (2005), "Nominal Rigidity, Desired Markup Variations and Real Exchange Rate Persistence", Journal of International Economics, 61, 49-74.

[12] Boulhol H., S. Dobbelaere and S. Maioli (2006), "Imports as Product and Labour Market Discipline", IZA Discussion Paper, 2178.

[13] Burstein A., M. Eichenbaum and S. Rebelo (2007), "Modeling exchange rate pass-through after large devaluations", Journal of Monetary Economics 54 346–368.

[14] Burstein, A., M. Eichenbaum and S. Rebelo (2005), "Large devaluations and the real exchange rate", Journal of Political Economy, 113 (4), 742–784.

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

[16] Calvo G. (1983), "Staggered prices in a utility-maximizing environment", Journal of Monetary Economics, 12, 983-998.

[17] Campa J.M. and L. Goldberg (2005), "Exchange rate pass-through into import prices", Review of Economics and Statistics, 87 (4), 679-690.

[18] Campa J.M. and J.M. Gonzalez-Minguez (2006), "Differences in Exchange rate pass-through in the euro area", European Economic Review, 50, 121-145.

[19] Chari V., P. Kehoe, and E. McGrattan (2000), "Sticky Price Model of the Business Cycle: Can the Contract Multiplier Solve the Persistence Problem?", Econometrica, 68, 1151–1179.

[20] Chari V., P. Kehoe, and E. McGrattan (2002), "Can Sticky Price Models Generate Volatile and Persistent Real Exchange Rates", Review of Economic Studies, 69, 533-563.

[21] Coenen G. and A. Levin (2004), "Identifying the influences of nominal and real rigidities in aggregate price-setting behavior", European Central Bank, Working Paper, 418.

[22] Corsetti G., L. Dedola and S. Leduc (2007), "Optimal monetary policy and the sources of local-currency price stability", mimeo, September.

[23] Corsetti G., L. Dedola and S. Leduc (2006), "DSGE models with High Exchange-Rate Volatility and Low Pass-through", International Finance Discussion Papers of the Federal Reserve Board, 845.

[24] Corsetti G. and L. Dedola (2005), "Macroeconomics of international price discrimination",.Journal of International Economics, 67, 129-155.

[25] Daly D., R. Hellerstein, and Ch. Marsh (2006), "Have U.S. Import Prices Become Less Responsive to Changes in the Dollar?", Current Issues in Economics and Finance, 12 (6), 1-7, Federal Reserve Bank of New York, September.

[26] de Walque G., Smets F. and R. Wouters (2005), "An estimated two-country DSGE model for the Euro area and the US economy", mimeo, National Bank of Belgium.

[27] Dornbusch R. (1987), "Exchange Rates and Prices", American Economic Review, 77, 93-106.

[28] Dossche M., F. Heylen, and D. V. den Poel (2006): "The Kinked Demand Curve and Price Rigidity: Evidence from Scanner Data", Working Paper 99, National Bank of Belgium.

[29] Dotsey M. and R. King (2005), "Implications of State-Dependent Pricing for Dynamic Macroeconomic Models", Journal of Monetary Economics, 52, 213–242.

[30] Eichenbaum M. and J. Fisher (2004), "Evaluating the Calvo Model of Sticky Prices", National Bureau of Economics Research Working Paper, 10617, June.

[31] Erceg C., D. Henderson and A. Levin (2000), "Optimal monetary policy with staggered wage and price contracts", Journal of Monetary Economics, 46(2), 381-413.

[32] Goldberg P. and R. Hellerstein (2007), "A Framework for Identifying the Sources of Local Currency Price Stability with an Empirical Application", Federal Reserve Bank of New York Staff Reports, 287, June.

[33] Gust C. and N. Sheets (2006), "The Adjustment of Global External Imbalances: Does Partial Pass-through to Trade Prices Matter?", Board of Governors of the Federal Reserve System, International Finance Discussion Papers, 850, January.

[34] Gust C., S. Leduc, and R. Vigfusson (2006), "Trade Integration, Competition, and the Decline in Exchange Rate Pass-through", International Finance Discussion Paper, 864, August.

[35] Ihrig J., M. Marazzi, and A. Rothenberg (2006), "Exchange Rate Pass-through in the G-7 Economies", International Finance Discussion Paper, 851, January.

[36] Kimball M. (1995), "The quantitative analytics of the basic neomonetarist model", Journal of Money, Credit and Banking, 27, 1241-1277.

[37] Klenow, P. and J. Willis (2006), "Real Rigidities and Nominal Price Changes", Federal Reserve Bank of Kansas City Research Working Paper, 06-03, March.

[38] Landry A. (2006), "Expectations and Exchange Rate Dynamics: A State-Dependent Pricing Approach", Federal Reserve Bank of Dallas Working Paper, 0604, November.

[39] Lane P. (2001), "The new open economy macroeconomics: a survey", Journal of International Economics, 54, 235-266.

[40] Levin A., J. Lopez-Salido, T. Yun (2007), "Strategic complementarities and optimal monetary policy" Kiel Working Paper, 1355, June.

[41] Lubik, T. and F. Schorfheide (2006), "A Bayesian look at new open economy macroeconomics", NBER Macroeconomics Annual 2005, 20, 313-366.

[42] Marazzi, M. and N. Sheets (2007), "Declining Exchange Rate Pass-through to U.S. Import Prices: The Potential Role of Global Factors", Journal of International Money and Finance, 26, 924-947.

[43] Marazzi M, N Sheets, R Vigfusson, J Faust, J Gagnon, J Marquez, R Martin, T Reeve and J Rogers (2005), "Exchange rate pass-through to U.S. import prices: some new evidence", Board of Governors of the Federal Reserve System International Finance Discussion Papers, 833, April.

[44] Mendoza, E (1995), "The terms of trade, the real exchange rate and economic fluctuations", International Economic Review, 36 (1), 101-137.

[45] Mishkin F. (2008), "Exchange rate pass-through and monetary policy", National Bureau of Economics Research Working Paper, 13889, April.

[46] Obstfeld M. and K. Rogoff (1995), "Exchange Rate Dynamics Redux", Journal of Political Economy, 103, 624-660.

[47] Obstfeld M. and K. Rogoff (1998), "Risk and Exchange Rates", National Bureau of Economics Research Working Paper, 6694.

[48] Obstfeld M and K. Rogoff (2000), "New directions for stochastic open economy models", Journal of International Economics, 50, 117-153.

[49] Sbordone A. (2008), "Globalization and inflation dynamics: the impact of increased competition",.Federal Reserve Bank of New York, Staff Reports, 324, April.

[50] Sekine T. (2006), "Time-Varying Exchange Rate Pass-through: Experiences of Some Industrial Countries", Bank for International Settlements Working Paper, 202, March.

[51] Smets F. and R. Wouters (2002), "Openness, imperfect exchange rate pass-through and monetary policy", Journal of Monetary Economics, 49, 913-940.

[52] Smets F. and R. Wouters (2003a), "An estimated dynamic stochastic general equilibrium model of the euro area", Journal of the European Economic Association, 1, 1123-1175.

[53] Smets F. and R. Wouters (2003b), "Shocks and frictions in US business cycle fluctuations: a Bayesian DSGE approach", Mimeo.

[54] Schmitt-Grohé S. and M. Uribe (2003), "Closing small open economy models", Journal of International Economics, 61, 163-185.

[55] Woodford M. (2005), "Firm-specific capital and the New Keynesian Phillips Curve", International Journal of Central Banking, 1, 1-46.

[56] Woodford M. (2003), Interest and Prices, Princeton University Press, New Jersey.

Table 3: List of variables used in figures

Variable	Symbol
Optimal import price	$\widetilde{p}_f^T$
Optimal traded goods price	$\widetilde{p}_h^T$
Optimal export price	$\widetilde{p}_h^*.S$
Import price at the border	P_F^T
Traded good price	P_H^T
Export price	$P_H^{T*}.S$
Retail import price	P_F^{TD}
Consumption price	P
Non-traded goods price	P^N
CPI inflation	π
Real wages	W/P
Output	$Y_h^T + Y^N$
Output: traded; non-traded	Y_h^T; Y^N
Consumption	C
Imports	Y_F^T
Terms of trade	$s + P_H^{T*} - P_F^T$
Trade balance	Υ
Exchange rate	S
Real exchange rate	RS

Figure 1-a. UIRP shock: 10% depreciation

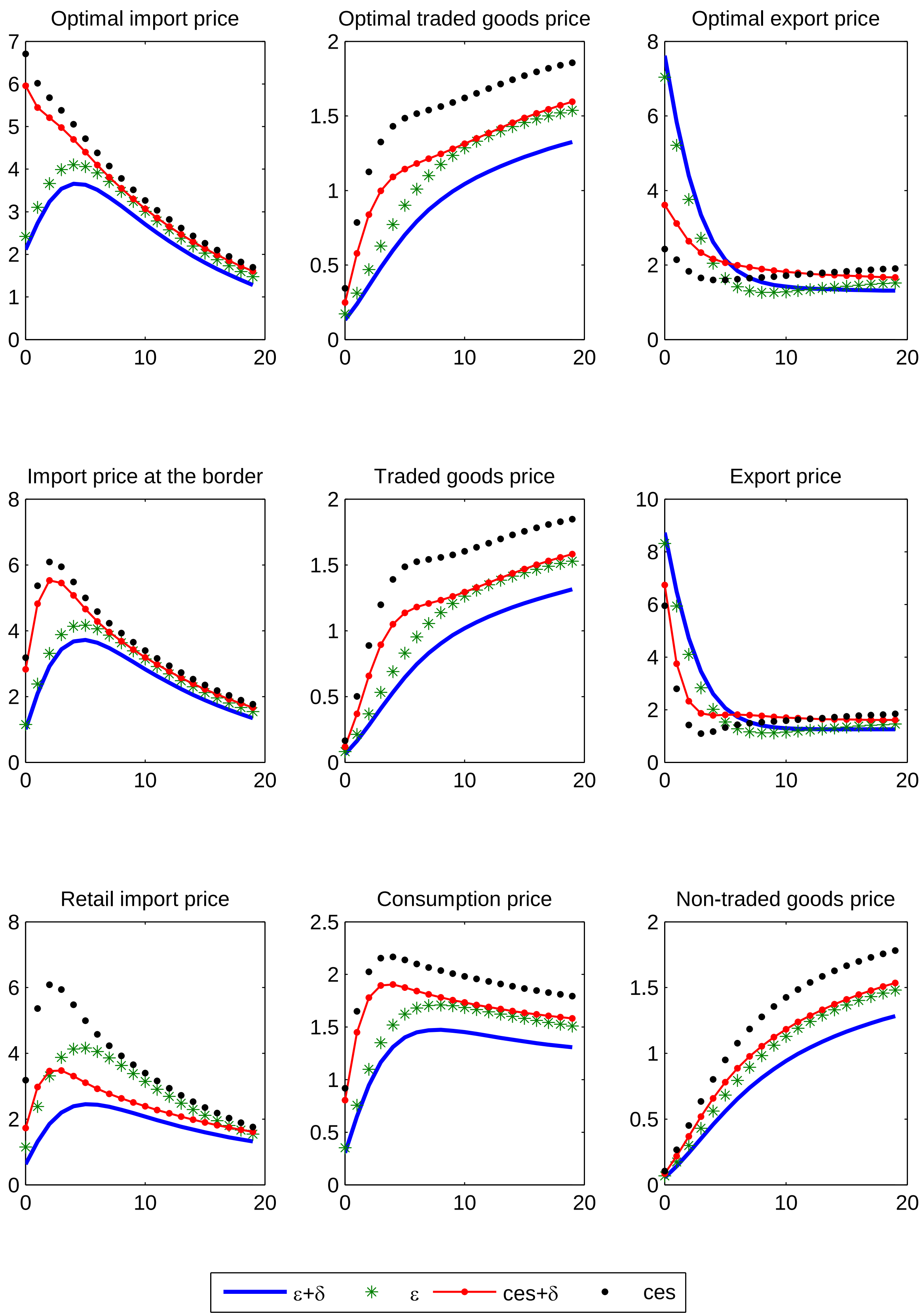


Figure 1-b. UIRP shock: 10% depreciation

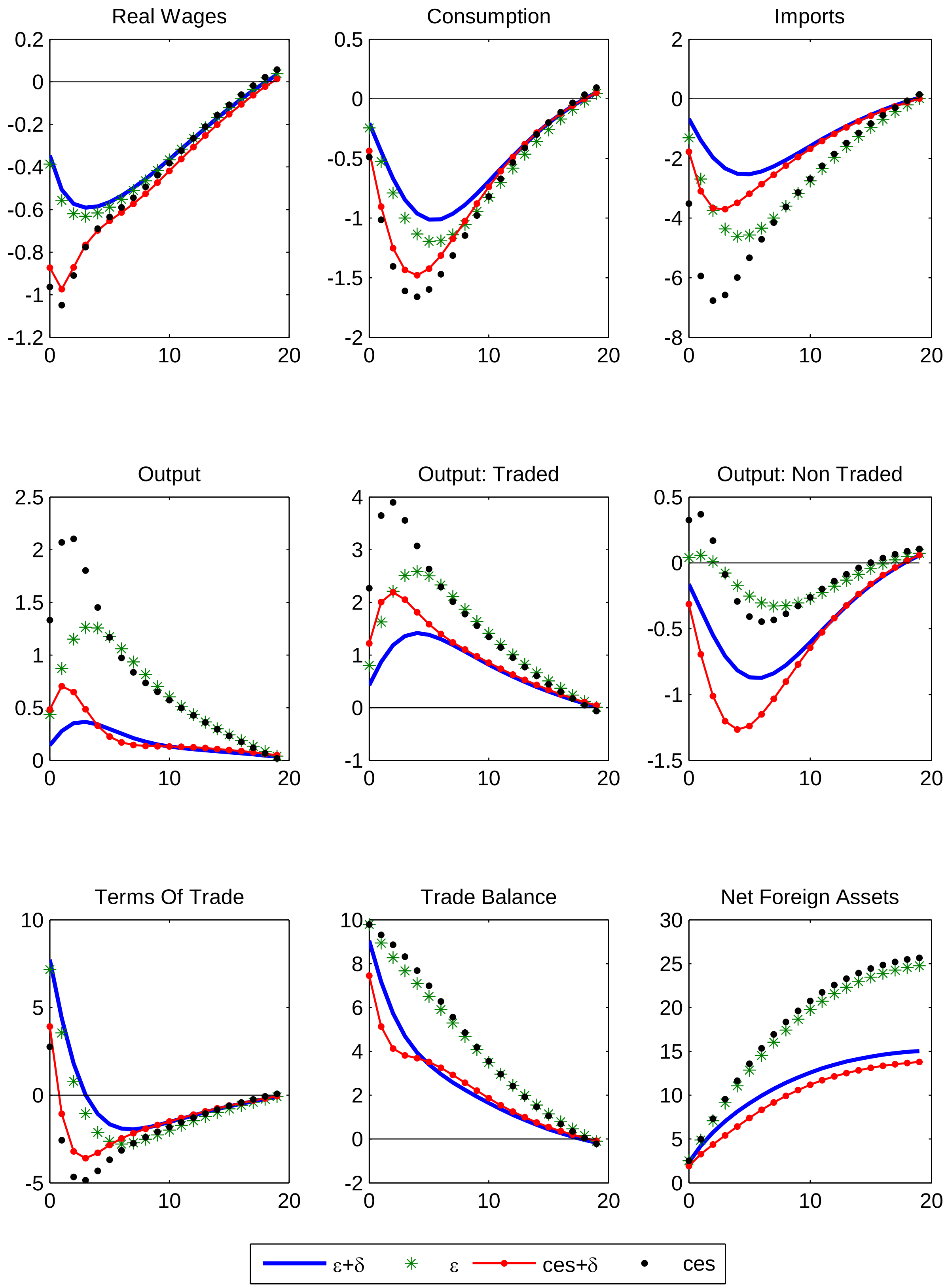


Figure 1-c. UIRP shock: 10% depreciation

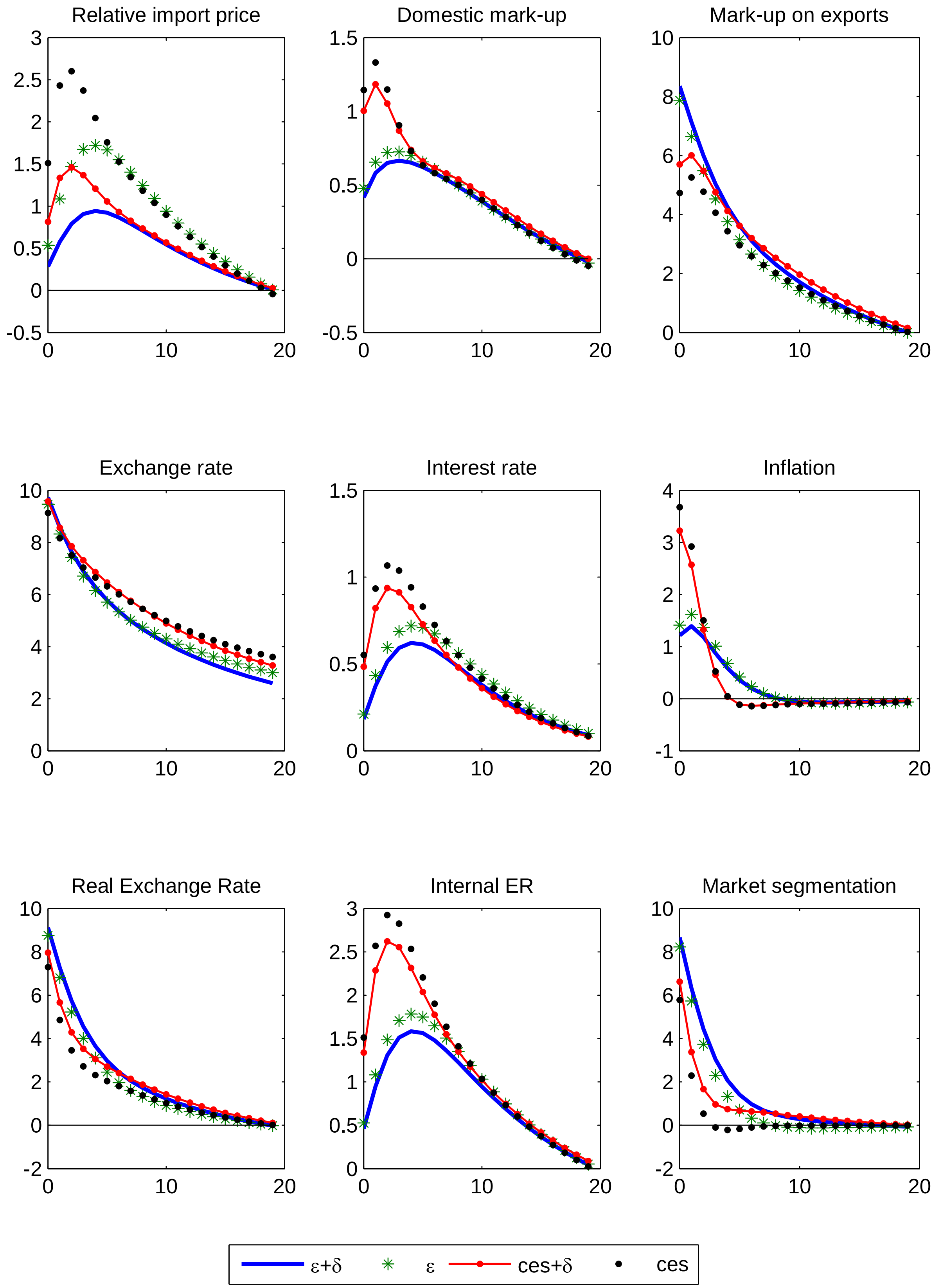


Figure 2-a: Increase in Trade Openness

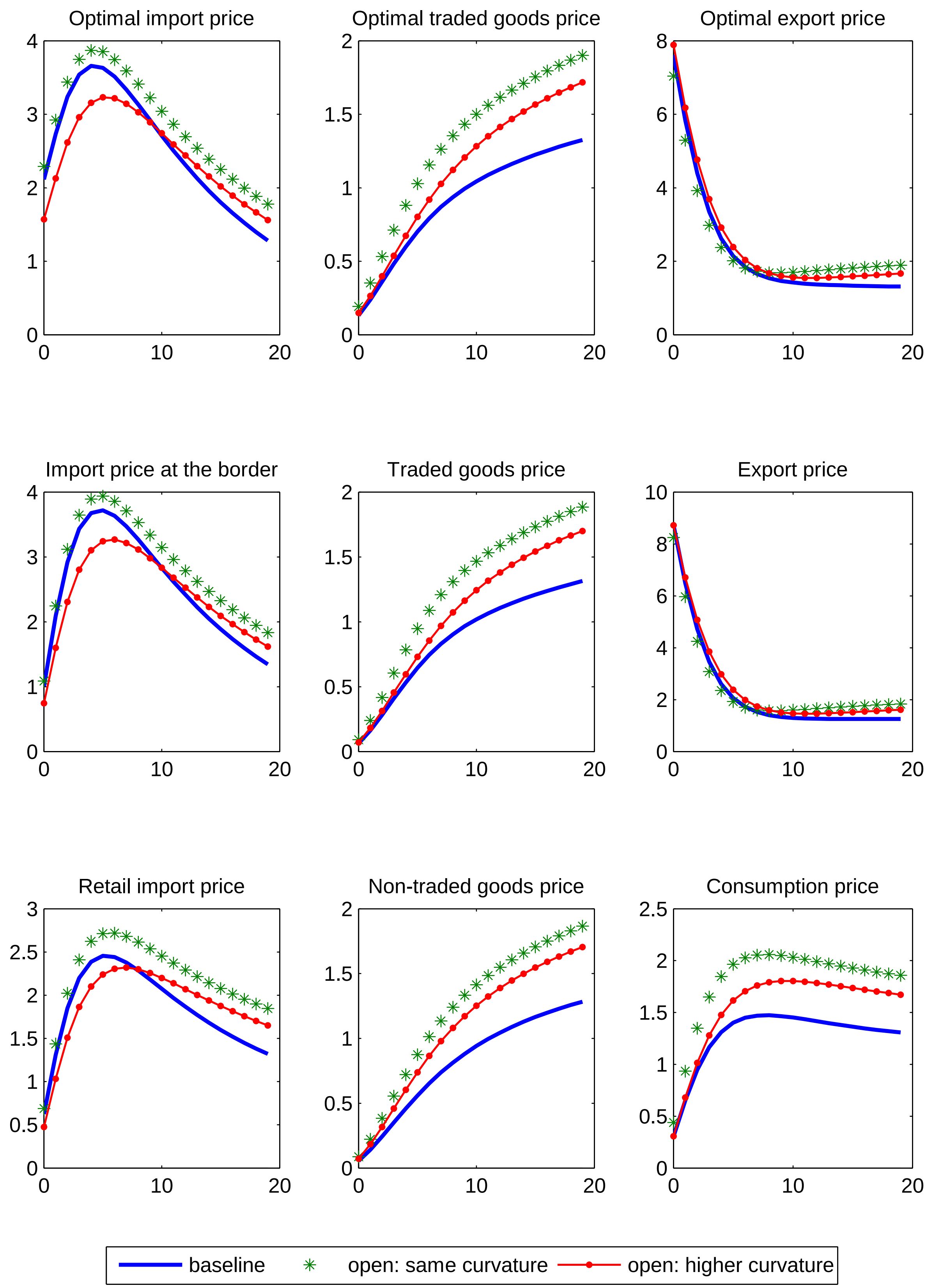
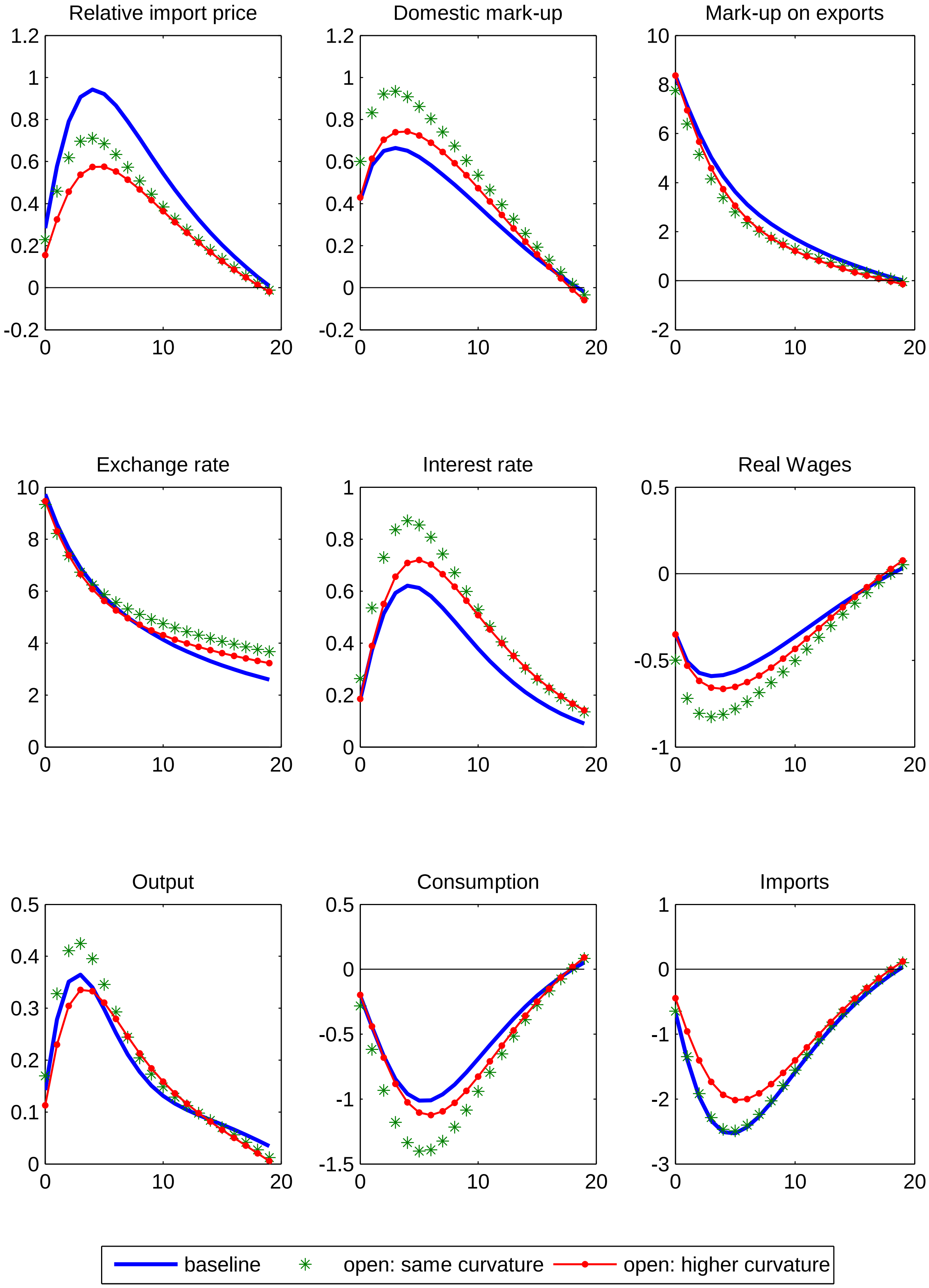


Figure 2-b: Increase in Trade Openness



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Jan Smets

Member of the board of Directors of the National Bank of Belgium

Layout: NBB Microeconomic Analysis
Cover: NBB TS – Prepress & Image

Published in August 2008