Endogenous Exchange Rate Pass-Through with Imported Intermediates[1]

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Abstract

This paper develops a model for endogenous exchange rate pass-through when imports also serve as inputs for production. After deriving the conditions for firms in which currency to set prices, we show that the presence of imported intermediates modifies the variance and covariance structure between nominal exchange rate and firms' costs. Consequently, the currency selection problem will also be changed, as well. Then, the equilibrium proportion of firms with Local Currency Pricing strategy was determined by a general equilibrium model with sticky prices, wages and imported intermediates. The simulations have shown that incorporating imported intermediates into the production function would change firms' pricing strategies. For any given share of imported intermediates, the conclusions of the benchmark model (without imported intermediates) still hold: e.g. fixing the exchange rate, monetary instability and small country size decreases the pass-through of exchange rate to export prices. The model with imported goods in the production function gives similar results to the benchmark model for small countries, fixed exchange rates and relatively high Home monetary instability. However, in a large country, or in a country with domestic monetary stability, the share of exporting firms opting for local currency pricing policies increases if production requires imported intermediates. We found that the presence of imported intermediates might alter the optimal monetary policy implications of Devereux et al. (2003). Though their conclusions remain valid in the case when there are no imported goods in production, the exchange rate pass-through might be sensitive to the import content of production. Our model shows that in some circumstances inward-looking (which only focuses on stabilising domestic inflation) and in other circumstances outward looking (which focuses on both stabilising domestic and imported inflation) monetary policy will be optimal. The choice between different monetary strategies depends on the importance of imported intermediates in production.

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Contents

1 Introduction

In traditional New Open Economy Models monetary policy which stabilises domestic inflation will minimise the welfare costs associated with staggered price (and wage-) setting, as well. These models handle imports as consumption goods, and imports are only determined by the intra- and intemporal choice of consumers'. However, major share of imports in international trade can be treated as intermediates, they mostly serve as an input to production. Intuitively, when production (import) costs are affected by monetary policy actions through movements in the nominal exchange rate, optimal monetary policy should also focus on stabilising imported inflation, as well. However, McCallum-Nelson (2001) argues that even if imported raw materials are used in production, there is less of a contrast between controlling inflation in an open economy and controlling inflation in a closed economy. On the other hand, according to Smets-Wouters (2002) in the case of imported intermediates and imperfect pass-through, a central bank that wants to minimise the resource costs of staggered price setting will aim at minimising a weighted average of domestic and import price inflation. Devereux et al. (2003) proposes a new argument in favour of following inward-looking monetary policy (which stabilisies domestic inflation) in open economies. They show that if domestic monetary policy achives stabilisation of domestic money growth rate, it encourages foreign exporters to set prices in terms of its currency. Hence, this policy would also stabilise imported inflation, as well. Thus, allowing for endogenous exchange rate pass-through may have significant implications for optimal monetary policy.

This paper tries to add to the debate on optimal monetary policy in an open economy by putting endogenous pass-through and imported intermediates together. As a first step, we show how conditions on the firms choice in which currency they set their price is modified if there are imported intermediates. Secondly a general equilibrium model with sticky prices, wages and imported intermediates was set up. We show also, how this model generates an expenditure switching effect of nominal exchange rate fluctuations. Thirdly, this general equilibrium model and the conditions on the determination of firms' pricing policies were put together. We show how the presence of imported intermediates would change the results of an endogenous exchange rate pass-through model. The effects of country size, exchange rate regimes and monetary stability are analysed with and without imported intermediates.

2 Determination of Pricing Policies in the Case of Imported Intermediates

There is a vast literature on long run price setting behaviour of exporting firms (e.g. Obstfeld-Rogoff (2000), Devereux-Engel (2000), Betts-Devereux (2000), Lane (2001)). Exchange rate pass-through to both consumer and import prices might be incomplete, when prices and wages are set in advance. When prices are sticky, one can treat aggregate exchange rate pass-through as a result of firms' choices on which currency to be "sticky". In this setting the degree of aggregate pass-through is the ratio of Producer Currency Pricing (PCP) firms (the remainder of firms follow Local Currency Pricing (LCP) policies). When all firms are PCP price setters, there is a full exchange rate pass-through to import prices. On the other extreme when all firms in both Foreign and Home countries are LCP price setters, exchange rate pass-through is far from complete. In this section I show how the decision of a firm on which currency it "prices" can be determined in an environment, when costs and sales are stochastic and when costs also depend on both wages and import prices. Though the analysis below largely builds on the results of Devereux-Engel-Storgaard (2003), there are significant differences. Firstly, in this set up, firms not only choose labour input, but also determine their demand for imported intermediates. Secondly, there is a substitution effect related to the choice between using labour and imported intermediates. These will largely, though not conceptionally, modify the results of Devereux et al. (2003).

In this section I develop the conditions on exchange rates, wages and the price of imported intermediates, under which the firm will choose to price in its own currency or the currency of its export market. In the next section, I will describe how this condition depends on the macroeconomic environment, by setting up a sticky price-sticky wage general equilibrium model with two factors of production in the Home country, labour and imported intermediates.Take a firm i in the Home country exporting a differentiated good to a foreign market. Assume that the exporting firm faces a CES demand curve

$$Y(P(i)) = (\frac{P(i)}{P})^{-\lambda}(\frac{P}{P^*})^{-\theta}Y^* \tag{1}$$

Where $P(i)$ is the price of the foreign consumer pays for good i. P is the price index for all Home goods purchased by the foreign consumer, P^* is the foreign country consumer price index. Y^* denotes a demand shift variable which is independent of prices (however, it will depend on aggregate foreign wages and import prices). Here we also assume that foreign import demand does not depend on the firm's choice on its prices, as the firm is small relative to the market. It depends on aggregate foreign import prices and foreign wages. Hence, in this section we first treat P^* and Y^* exogenously. Next section will elaborate on the determination on these very important variables in a general equilibrium setting. λ is the price elasticity of consumer demand facing the domestic firm i, while θ is the foreign price elasticity of demand for domestic consumer goods (λ, θ>0). The firm is a small enough supplier that it cannot influence P and P^*, foreign wages and foreign aggregate import prices. As in the model of Smets-Wouters (2002), Home firm has a Leontieff production function with respect to labour ($L(i)$) and imported intermediates ($I(i)$).

$$Y(i) = \min(\frac{L(i)}{\alpha}, \frac{I(i)}{1-\alpha}) \tag{2}$$

Where α refers to the share coefficient ($\alpha \in [0, 1]$). It can be easily shown that the Home firm's marginal (and unit) cost.

$$MC(i) = \alpha W + (1-\alpha)P_f \tag{3}$$

and W_t and P_{ft} denotes wage and the price of imported intermediates, respectively. From cost-minimisation one can easily derive factor demands ((4) and (5)).

$$L(i) = \alpha Y(i) \tag{4}$$

$$I(i) = (1-\alpha)Y(i) \tag{5}$$

For simplicity we assume that Foreign production does not require imported intermediates[1]. For convenience we assume that it is linear in Foreign labour. This also implies linear marginal cost function abroad, as well.

$$Y^*(i) = L^*(i) \tag{6}$$

$$MC^*(i) = W^* \tag{7}$$

We assume, that all prices are set in advance, hence regardless of the pricing policy (LCP or PCP), firms must set their prices before the state of the economy is known. Hence throughout this paper we assume that prices are sticky, the question is in which currency they are. In the case when the firm opts for PCP pricing strategy, its expected discounted profit is

$$E(\pi^{PCP}) = E(d\left\{P^{PCP}(i) - MC(i)\right\}\left[\frac{P^{PCP}(i)}{SP}\right]^{-\lambda}\left[\frac{P}{P^*}\right]^{-\theta} Y^* \tag{8}$$

In the case of LCP pricing policy expected discounted profit is

$$E(\pi^{LCP}) = E(d\left\{SP^{LCP}(i) - MC(i)\right\}\left[\frac{P^{LCP}(i)}{P}\right]^{-\lambda}\left[\frac{P}{P^*}\right]^{-\theta} Y^* \tag{9}$$

Where S is the nominal exchange rate and d is the (stochastic) discount factor, which does not depend on the firm's prices (in turn, it will be endogenous in the general equilibrium model). Firms operate in a monopolistically competitive environment, hence they are price-setters. It can be easily shown that the profit maximising (optimal) prices of the Home firm under PCP and LCP are as follows:

$$P^{PCP}(i) = \frac{\lambda}{\lambda-1}\frac{E([\alpha W + (1-\alpha)P_f]\, ZS^{\lambda})}{E(S^{\lambda}Z)} \tag{10}$$

$$P^{LCP}(i) = \frac{\lambda}{\lambda-1}\frac{E([\alpha W + (1-\alpha)P_f]\, Z)}{E(SZ)} \tag{11}$$

where $Z = dP^{-\theta+\lambda}(P^*)^{\theta}Y^*$. Z captures all variables which are independent of the firm's decision. Optimal prices of the Foreign firm can be determined analogously without having price of imported intermediates in the formula.

[1] The inclusion of imported intermediates would complicate the model, without modifing its qualitative properties.

Firms set prices as a mark-up over expected marginal costs. Using these pricing conditions expected profits of the Home firm under different pricing policies are as follows:

$$E(\pi^{PCP}) = \widetilde{\lambda} \left[E(\{\alpha W + (1-\alpha)P_f\}\, S^{\lambda} Z)\right]^{1-\lambda} \left[E(S^{\lambda} Z)\right]^{\lambda} \tag{12}$$

$$E(\pi^{LCP}) = \widetilde{\lambda}\, [E(\{\alpha W + (1-\alpha)P_f\}\, Z)]^{1-\lambda}\, [E(SZ)]^{\lambda} \tag{13}$$

where $\widetilde{\lambda} = \left(\frac{\lambda}{\lambda-1}\right)^{-\lambda} \frac{1}{\lambda-1}$. Expected profits are then a special "Cobb-Douglas aggregates" of the nominal exchange rate, demand and cost items. After log-linearising (12) and (13) and taking a second-order Taylor-approximation around the steady state, we arrive atthe condition which shows us under what circumstances the firm will choose LCP or PCP.

Proposition 1 *Choice of pricing strategy, when there are imported intermediates in the production. The Home firm will set its export price in Home currency (PCP) if*

$$\frac{var(s)}{2} - [\alpha cov(s, w) + (1-\alpha)cov(s, p_f) + \alpha(1-\alpha)cov(w, p_f)] > 0 \tag{14}$$

where $s = \ln(S), w = \ln(W),\ p_f = \ln(P_f)$.

Proof: Assuming that in steady state $P_{ft} \sim W_t$[2] *after second order approximate (12) and taking logarithms we get an expression for expected discounted profits under PCP. Doing the same for (13) we arrive at Proposition 1.*

Home firms will choose PCP pricing, when (1) the nominal exchange rate is highly volatile, or when (2) wages and the costs of imported intermediates are highly positively correlated with the nominal exchange rate. Moreover, the correlation between wage and imported costs should be also taken into account. The condition highlights that the Home firm is more likely to choose LCP pricing when it is "naturally" hedged against exchange rate fluctuations, i.e. the correlation of costs with the nominal exchange rate and the cross-correlation between different cost-components compensates for the volatility in the revenues (determined by nominal exchange rate fluctuations). In this case, the mark-up of the firm will accommodate such that it compensates for the gains and losses resulting from exchange rate fluctuations.

From this condition one can conclude that there are two channels in optimal pricing: the decision depends on the volatility of the nominal exchange rate; the more volatile the nominal exchange rate, the more incentive to choose PCP-strategy. LCP strategy is preferred when the firm is naturally hedged against exchange rate fluctuations. When there are no imported intermediates ($\alpha = 1$) we arrive back to the condition derived by Devereux et al. (2003) (see 15).

$$\frac{var(s)}{2} - cov(s, w) > 0 \tag{15}$$

[2] It can be easily shown that this condition holds if the deviation of nominal exchange rate to its steady state level is zero.

As foreign production does not require imported intermediates the condition which determines the pricing policy is similar to that derived by Devereux et al. (2003). Foreign firms face the same "hedging" problem, but they should only take care of how their wage costs are correlated with exchange rate fluctuations.

Proposition 2 *Conditions on the choice of PCP pricing policy for the Foreign firm. Foreign firm will set its export price in Foreign currency (PCP) if*

$$\frac{var(s)}{2} + cov(s, w^*) \succ 0 \tag{16}$$

where $w^* = \ln(W^*)$.

Proof: Expected discounted profits for the Foreign firm can be written as follows.

$$E(\pi^{*PCP}) = \widetilde{\lambda}\left[E(W^* S^{-\lambda} Z^*)\right]^{1-\lambda}\left[E(S^{-\lambda} Z^*)\right]^{\lambda} \tag{17}$$

$$E(\pi^{*LCP}) = \widetilde{\lambda}\left[E(W^* P_h Z^*)\right]^{1-\lambda}\left[E(S^{-1} Z^*)\right]^{\lambda} \tag{18}$$

After second order approximate (17) and taking logarithms we get an expression for expected discounted profits under PCP. Doing the same for (18) we arrive at Proposition 2.

In the next section the equilibrium level of pass-through (the share of PCP firms) will be determined by using Proposition 1. and 2. where the variance and covariance terms will become endogenous.

3 General Equilibrium Model

3.1 Outline of the model

In the previous section the decision of the currency in which prices are sticky were determined given the distribution of costs and the nominal exchange rate. This section shows a general equilibrium model of nominal exchange rate determination given the pricing policies decided by the firms (see previous section). The core part of the model is taken from the open economy model of Devereux et al. (2003) (which is based on Obstfeld-Rogoff (1995) and Blanchard-Kiyotaki (1987)). As mentioned before, the major difference is that here we have imported intermediates in the production function of Home firms. Though, this difference will complicate the way the nominal exchange rate is determined, the results will be conceptually similar to that of Devereux et al. (2003).

There are two countries: Home and Foreign, with consumers, government and firms in each country. There are n households and firms in the Home country, and $1 - n$ in the Foreign country. Foreign variables are denoted with an asterisk. All firms have monopoly (pricing) power in affecting the price of their own output, while workers have monopoly power in the labour market in setting their wages.

3.1.1 Consumers' problem

Each consumer k in the Home country maximises expected lifetime utility:

$$U_t(k) = E_t \sum_{s=t}^{\infty} \beta^{s-t} u_s(k) \tag{19}$$

where

$$u_s(k) = \frac{C_s(k)^{1-\rho}}{1-\rho} + \chi \ln(\frac{M_s(k)}{P}) - \frac{\eta}{1+\psi} L_s(k)^{1+\psi} \tag{20}$$

$C_s(k)$ denotes aggregate consumption, $\frac{M_s(k)}{P_s}$ refers to real money balancec and $L_s(k)$ is labour supply at time s. As well known, aggregate consumption can then be calculated by an index of consumption of Home and Foreign goods.

$$C(k) = \left[n^{1/\theta} C_h(k)^{\frac{\theta-1}{\theta}} + n^{1/\theta} C_f(k)^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}}$$

where consumption of Home and Foreign goods is a composite of continuum of goods of n and $1-n$ goods, respectively.

Consumption of Home goods by Home consumers: $C_h(k) = \left[n^{-1/\lambda} \int_0^n C_h(i)^{\frac{\lambda-1}{\lambda}} di \right]^{\frac{\lambda}{\lambda-1}}$ and

Consumption of Foreign goods by Home consumers: $C_f(k) = \left[(1-n)^{-1/\lambda} \int_n^1 C_f(i)^{\frac{\lambda-1}{\lambda}} di \right]^{\frac{\lambda}{\lambda-1}}$

The (Home) consumer price index (minimum cost of acquiring 1 unit of aggregate consumption) is then $P_t = \left[n {P_{ht}}^{1-\theta} + (1-n) {P_{ft}}^{1-\theta} \right]^{\frac{1}{1-\theta}}$,where P_{ht} and P_{ft}denotes the price index of Home and Foreign goods sold in the Home country, respectively. Prices in each period are set in advance. All goods sold at Home are naturally prices in Local Currency (LCP), while fraction z (z^*) of Home (Foreign) goods are priced with LCP abroad (at Home). We will show later in the next section how z and z^* can be determined. Now, we take them as given. Using this assumption the price index of Foreign goods sold at Home is:

$$P_{ft} = \left[\frac{1}{1-n} \int_{n}^{n+(1-z^*)(1-n)} (S_t P^*_{fht}(i))^{1-\lambda} di + \frac{1}{1-n} \int_{n+(1-z^*)(1-n)}^{1} P_{fht}(i)^{1-\lambda} di \right]^{\frac{1}{1-\lambda}}$$

where $P^*_{fht}(i)$ and $P_{fht}(i)$ represents the foreign and Home currency price of foreign goods sold at Home, respectively.

As far as the behaviour of Foreign consumers is concerned, the model is symmetric: Foreign households face the same problems. It can be shown, that the pass-through is related to z^*. A zero value of z^* leads to full pass-through of exchange rate to the price of imported goods. When z^* is unity, the pass-through is zero. The converse holds for z for the Foreign pass-through coefficient. Risk sharing is incomplete, consumers can only trade non-contingent nominal bonds abroad.

3.1.2 Production and factor demands

As mentioned before, Home firms produce by using labour and imported intermediates, with constant returns to scale. Labour is differentiated, with elasticity of demand ω between different types of labour. Each firm uses all types of workers. Production function for firm i in the Home country is

$$Y(i) = \min(\frac{L(i)}{\alpha}, \frac{I(i)}{1-\alpha})$$

with a differentiated labour input consisting of n types of labour.

$$L_t(i) = \left[\frac{1}{n}\int\limits_0^n L_t(i,k)^{1-\frac{1}{\omega}} dk\right]^{\frac{1}{1-\frac{1}{\omega}}}$$

where $L(i,k)$ refers to the demand of firm i for the kth type of labour. Foreign firm uses only labour with a linear technology:

$$Y^*(i) = L^*(i)$$

where $L^*(i)$ is again a composite of different types of labour.

$$L_t^*(i) = \left[\frac{1}{1-n}\int\limits_n^1 L_t(i,k)^{1-\frac{1}{\omega}} dk\right]^{\frac{1}{1-\frac{1}{\omega}}}$$

Wage indices can then be determined by

$$W_t = \left[(\frac{1}{n})^{\frac{1}{\omega}}\int\limits_0^n W_t(k)^{1-\omega} dk\right]^{\frac{1}{1-\omega}}$$

$$W_t^* = \left[(\frac{1}{1-n})^{\frac{1}{\omega}}\int\limits_n^1 W_t^*(k)^{1-\omega} dk\right]^{\frac{1}{1-\omega}}$$

given the distribution of wages $(W(k))$. The specification of the production function enables us to separate the problem of first solving for aggregate labour and imported intermediates demand, and then calculating individual labour demands.

$$L(i) = \alpha Y(i)$$

$$I(i) = (1-\alpha)Y(i)$$

The ith firm demand for labour demand for type k is

$$L_t(i,k) = \left[\frac{W_t(k)}{W_t}\right]^{-\omega} L_t(i)$$

3.1.3 Labour supply

This shows that each worker faces a specific labour demand, with elasticity of demand equal to ω. As workers have monopoly power in the labour market and they own all firms labour supply relates real wages as the wage mark-up times the marginal rate of substitution between leisure and consumption.[3] Wage mark-up depends on the wage elasticity of labour demand.

$$\frac{W_t(k)}{P_t} = \frac{\omega}{\omega - 1} \frac{E_t(U_l(..))}{E_t(U_c(..))} \tag{21}$$

In equilibrium all labour will be priced at the same wage except that there remains a distinction between different types of labour which has fixed and adjusted wage. In the goods market exported goods with PCP and LCP pricing policies are different.

In symmetric equilibrium we might drop the index i, as all firms of the same type are similar. After substituting for the utility function nominal wage of those workers which adjust their wage flexibly

$$W_t^a = \frac{\omega\eta}{\omega - 1} P_t C_t^\rho (L_t^a)^\psi \tag{22}$$

and of those which have fixed wages:

$$W_t^f = \frac{\omega\eta}{\omega - 1} \frac{E_{t-1}((L_t^f)^{1+\psi})}{E_{t-1}(\frac{L_t^f}{P_t C_t^\rho})} \tag{23}$$

Denote the share of workers with adjustable wages by υ, the wage index is then:

$$W_t = \left[\upsilon (W_t^a)^{1-\omega} + (1-\upsilon)(W_t^f)^{1-\omega}\right]^{\frac{1}{1-\omega}}$$

This enables us to articulate labour demand for both adjusted and fixed wage labour.

$$L_t^a = \upsilon L_t (\frac{W_t^a}{W_t})^{-\omega} = \alpha\upsilon (\frac{W_t^a}{W_t})^{-\omega} Y_t \tag{24}$$

$$L_t^f = (1-\upsilon) L_t (\frac{W_t^f}{W_t})^{-\omega} = \alpha(1-\upsilon)(\frac{W_t^f}{W_t})^{-\omega} Y_t \tag{25}$$

3.1.4 Price indices

Price indices in the symmetric equilibrium can then be easily calculated.Home consumer price index:

$$P_t = \left[n {P_{ht}}^{1-\theta} + (1-n){P_{ft}}^{1-\theta}\right]^{\frac{1}{1-\theta}}$$

[3] In the case of perfect competition in the labour market, the mark-up is one, which leads to a standard labour supply equation equating wages with marginal rate of substitution between leisure and consumption.

Home Import price index:

$$P_{ft} = \left[(1-z^*)(S_t P^*_{fht})^{1-\lambda} + z^* {P_{fht}}^{1-\lambda}\right]^{\frac{1}{1-\lambda}}$$

Foreign consumer price index:

$$P^*_t = \left[n{P^*_{ht}}^{1-\theta} + (1-n){P^*_{ft}}^{1-\theta}\right]^{\frac{1}{1-\theta}}$$

Foreign Import price index:

$$P^*_{ft} = \left[z{P^*_{hft}}^{1-\lambda} + (1-z)(\frac{P_{hft}}{S_t})^{1-\lambda}\right]^{\frac{1}{1-\lambda}}$$

3.1.5 Money demand and supply

Money demand (26) can be determined relatively easily from the utility maximisation (from (20)) together with the usual Budget Constraint of the consumer (27).

$$\frac{M_t}{P_t} = \chi C_t^{\rho} \frac{1+r_{t+1}}{r_{t+1}} \tag{26}$$

$$P_t C_t + M_t + B_t = (1+r_{t-1})B_{t-1} + M_{t-1} + W_t L_t + \Pi_t \tag{27}$$

where Π_t denotes total profits of all Home firms.

Money supply is assumed to follow a random walk in logarithms: $m_{t+1} = m_t + u_{t+1}$with $E_t(u_{t+1}) = 0$.[4]

3.1.6 Intertemporal choice

The Euler-condition for the intertemporal choice of consumption is the usual one:

$$\frac{C_t^{-\rho}}{P_t} = \beta(1+r_{t+1})E_t(\frac{C_{t+1}^{-\rho}}{P_{t+1}}) \tag{28}$$

We assume incomplete risk sharing which requires that the discount factor which profits are discounted should be equal to the (nominal) yield of saving one marginal unit of consumption. As the discount factor is stochastic at time $t-1$ it's value can be calculated with deterministic variables.

$$d_{t-1} = \frac{1}{1+r_t} = \beta \frac{C_{t-1}^{\rho} P_{t-1}}{C_t^{\rho} P_t} \tag{29}$$

[4] $m_t = \ln(M_t)$

3.1.7 Pricing policies

In the previous section we formulated the pricing functions. We have shown that export price of Home goods of Home PCP-pricer firms:

$$P_{hft} = \frac{\lambda}{\lambda - 1} \frac{E_{t-1}(Z_t S_t^{\lambda} \left[\alpha W_t + (1-\alpha) P_{ft}\right])}{E_{t-1}(Z_t S_t^{\lambda})} \tag{30}$$

Export price of Home goods of Home LCP-pricer firms:

$$P_{hft}^{*} = \frac{\lambda}{\lambda - 1} \frac{E_{t-1}(Z_t \left[\alpha W_t + (1-\alpha) P_{ft}\right])}{E_{t-1}(Z_t S_t)} \tag{31}$$

The domestic price of Home goods can be calculated by maximisation of expected discounted profits. Marginal costs are the same as in the exporting firms, while now the demand variable is simply domestic consumption.

$$P_{ht} = \frac{\lambda}{\lambda - 1} \frac{E_{t-1}(d_{t-1} C_{ht} \left[\alpha W_t + (1-\alpha) P_{ft}\right])}{E_{t-1}(d_{t-1} C_{ht})} \tag{32}$$

3.1.8 Market clearing conditions

Finally, we should add a resource – a balance of payments – condition: the consumption is financed by change in bond holdings plus interest income earned from bonds and total revenues from domestic and export sales net of profits in the import sector. As the production of Foreign goods only require (foreign) labour, and at the same these goods also serve as a factor of production at Home, Foreign exporters have a net revenue payed by Home consumers and firms. We treat this profit ($(P_{ft} - W_t^{*} S_t) I_t$) as an income of Foreign agents, the last term in the balance-of-payments shows this effect.

$$P_t C_t + B_{t+1} = (1 + r_t) B_t + P_{ht} Y_{ht} + (1 - z) P_{hft} Y_{hft} + z S_t P_{hft}^{*} Y_{hft}^{*} - \Pi_t^{i} \tag{33}$$

where $Y_{ht}, Y_{hft}, Y_{hft}^{*}$ denotes Home sales of Home goods, exports of PCP-firms and exports of LCP-firms, respectively. Market clearing requires that total production of Home goods sold ion the Home market equals to domestic goods consumption. Substituting in for the demand equation one arives:

$$Y_{ht} = C_{ht} = n \left[\frac{P_{ht}}{P_t}\right]^{-\theta} C_t \tag{34}$$

Demand for PCP and LCP exports of Home goods can be determined from foreign demand schedules. Total PCP exports are then:

$$Y_{hft} = (1 - n) \left[\frac{P_{hft}}{S_t P_{ht}^{*}}\right]^{-\lambda} \left[\frac{P_{ht}^{*}}{P_t^{*}}\right]^{-\theta} C_t^{*} \tag{35}$$

While total LCP exports are:

$$Y_{hft}^{*} = (1 - n) \left[\frac{P_{hft}^{*}}{P_{ht}^{*}}\right]^{-\lambda} \left[\frac{P_{ht}^{*}}{P_t^{*}}\right]^{-\theta} C_t^{*} \tag{36}$$

Profit in the Foreign import sector equals to total sales minus total costs:

$$\Pi_t^i = (P_{ft} - W_t^* S_t) I_t \tag{37}$$

3.2 Model solution

Model solution proceeds as follows: we first linearly approximate the model around its nonstochastic steady state when all prices and wages are equal Let denote $\hat{x}_t = \ln X_t - \ln X^{SS}$ as the log deviation of any variable x from its steady state value (X^{SS}). We will also use the property that $x_{t+j} = \ln X_{t+j} - E_{t-1} X_{t+j}$. The six pricing equations and the price indices can then be written in deviations from the steady state:

$$\hat{p}_t = n\hat{p}_{ht} + (1-n)\hat{p}_{ft} \tag{38}$$

$$\hat{p}_t^* = n\hat{p}_{ht}^* + (1-n)\hat{p}_{ft}^* \tag{39}$$

$$\hat{p}_{ht} = \alpha E_{t-1}\hat{w}_t + (1-\alpha)\hat{p}_{ft} \tag{40}$$

$$\hat{p}_{ht}^* = z\hat{p}_{hft}^* + (1-z)(\hat{p}_{hft} - \hat{s}_t) \tag{41}$$

$$\hat{p}_{ft} = (1-z^*)(\hat{p}_t + \hat{p}_{fht}^*) + z^*\hat{p}_{fht} \tag{42}$$

$$\hat{p}_{ft}^* = E_{t-1}\hat{w}_t^* \tag{43}$$

$$\hat{p}_{hft} = \alpha E_{t-1}\hat{w}_t + (1-\alpha)\hat{p}_{ft} \tag{44}$$

$$\hat{p}_{hft}^* = \alpha E_{t-1}\hat{w}_t + (1-\alpha)\hat{p}_{ft} - E_{t-1}\hat{s}_t \tag{45}$$

$$\hat{p}_{fht} = E_{t-1}\hat{w}_t^* + E_{t-1}\hat{s}_t \tag{46}$$

$$\hat{p}_{fht}^* = E_{t-1}\hat{w}_t^* \tag{47}$$

Using these conditions one can derive the import price index

$$\hat{p}_{ft} = (1-z^*)\hat{s}_t + z^* E_{t-1}\hat{s}_t + E_{t-1}\hat{w}_t^* \tag{48}$$

and thus

$$\hat{p}_t = \alpha n E_{t-1}\hat{w}_t + [1-\alpha n]\left[(1-z^*)\hat{s}_t + z^* E_{t-1}\hat{s}_t + E_{t-1}\hat{w}_t^*\right] \tag{49}$$

$$\hat{p}_t^* = \alpha n E_{t-1}\hat{w}_t + [1-\alpha n]\, E_{t-1}\hat{w}_t^* + [n(1-\alpha)z^* - nz]\, E_{t-1}\hat{s}_t + [n(1-\alpha)(1-z^*) - n(1-z)]\,\hat{s}_t \tag{50}$$

From (49) and (50) we can calculate the differentials of consumer price indices. This is the same as in the model without imported intermediates ($\alpha = 1$). Hence,though the price levels are effected by the presence of imported goods, relative prices are unchanged. (51) shows that relative consumer prices can only move with fluctuations in the nominal exchange rate.

$$p_t - p_t^* = (1 - nz - z^*(1-n))s_t \tag{51}$$

Linearising money demand functions (26) and its corresponding Foreign version one can arrive to a simple relationship

$$c_t = \frac{m_t - p_t}{\rho} \tag{52}$$

$$c_t^* = \frac{m_t^* - p_t^*}{\rho} \tag{53}$$

From (52) and (53) relative consumptions can also be determined

$$c_t - c_t^* = \frac{m_t - m_t^*}{\rho} - \frac{1 - nz - z^*(1-n)}{\rho} s_t \tag{54}$$

This is exactly the same as in Devereux et al. (2003). Hence, the presence of imported intermediates does not affect the determination of relative consumption (though it has strong implications for Home and Foreign consumption *levels*, but not on their differences). When there is a full pass-through ($z = z^* = 0$), PPP holds and (54) represents a "standard" monetary model of the exchange rate. Exchange rate fluctuations have an expenditure-switching effect by modifying the composition of world consumption. Linearising the balance-of-payments condition (33) and using the pricing equations ((38) to (47)) together with linearising (34) to (37), expected relative future consumption can be determined, as follows:

$$E_t(c_{t+1} - c_{t+1}^*) = \frac{r dB_{t+1}}{\varphi(1-n)\bar{P}\bar{C}} \tag{55}$$

where $\varphi = \frac{1+\psi\theta-\alpha\rho(1-\alpha\theta)}{1+\psi\theta}$ and $\bar{P}$ and $\bar{C}$ describes the steady state level of consumer prices and consumption, respectively. r is the steady state value of interest rate (equals to $\frac{1}{\beta} - 1$). (55) shows that a change in the nominal exchange rate works through an "expenditure-switching" effect, through its effect on relative net debt of the countries considered. The role of imported intermediates is that it modifies the relative importance of this "wealth-effect". For our baseline parameter setting (see Appendix) for any value of α φ is lower than without imported intermediates. Hence in the baseline setting wealth effects are magnified by the presence of imported goods in the production function. As $E_{t-1}d\hat{B}_{t+1} = d\hat{B}_t$ and r is constant at the steady state we arrive at the following. Combining (54) and (55) and again using the balance-of-payments condition (33) and the expressions for prices ((38) to (47)) and production ((34) to (37)) one can state that

$$c_t - c_t^* + \frac{\varphi}{r} E_t(c_{t+1} - c_{t+1}^*) = \begin{pmatrix} \{\alpha\theta - 1\}\left[\alpha n(1-z^*) + \alpha(1-n)(1-z)\right] \\ +\alpha\left[(1-n)z^* + nz\right] - (1-\alpha)\frac{z^*}{1-n} \end{pmatrix} s_t \tag{56}$$

(56) describes how income (wealth) effects of exchange rate movements are distributed between current and expected future consumption. In the case of $\alpha = 1$ we arrive back to that of Devereux et al. (2003).

Linearisation of Euler-conditions yields:

$$\widehat{p}_t + \rho\widehat{c}_t = E_t(\widehat{p}_{t+1} + \rho\widehat{c}_{t+1}) \tag{57}$$

$$\widehat{p}_t^* + \rho\widehat{c}_t^* = E_t(\widehat{p}_{t+1}^* + \rho\widehat{c}_{t+1}^*) \tag{58}$$

Conditions in (57) and (58) imply that

$$E_t(c_{t+1} - c_{t+1}^*) = c_t - c_t^* - \frac{zn + z^*(1-n)}{\rho} s_t \tag{59}$$

This expression is the same as in Devereux et al. (2003). The reason for this is that imported intermediates do not affect the intertemporal choice of consumption path (Euler-conditions) and they do not have an effect on price differentials, but on price levels only. (59) says that an unanticipated exchange rate depreciation for the Home country leads to a fall in expected consumption growth in the Home country, relative to the Foreign country. Combining (54), (55), (56) and (59) one obtains an equation for the nominal exchange rate.

$$s_t = \frac{1 + \frac{\varphi}{r}}{\Gamma}(m_t - m_t^*) \tag{60}$$

where

$$\begin{aligned}\Gamma \quad = \quad & zn + z^*(1-n) + (1 + \frac{\varphi}{r})(1 - nz - z^*(1-n)) + \\ & \rho\left\{(\alpha\theta - 1)\left[\alpha n(1 - z^*) + \alpha(1-n)(1-z)\right] + \alpha\left[(1-n)z^* + nz\right] - (1-\alpha)\frac{z^*}{1-n}\right\}\end{aligned}$$

where Γ depends on all the coefficients in the model, except for λ. The response of the nominal exchange rate to an unanticipated money shock depends on the elasticity of demand for Home goods, the intertemporal elasticity of substitution, the measure of LCP firms in both countries and last, but not least, the share of imported intermediates in production. Hence, in the case when there are imported intermediates, the level (and the volatility) of the nominal exchange rate is different than without them..

As $(1 - \upsilon)$ part of wages are fixed in both countries, the response of wages to money shock can be derived from the labour supply (24) and the Euler-conditions as:

$$w_t = \nu(m_t + \psi l_t^a) \tag{61}$$

$$w_t^* = \nu(m_t^* + \psi l_t^{*a}) \tag{62}$$

One can also compute the response of employment for the flexible labour in the two countries as:

$$l_t^a = -\omega(1-\nu)w_t^a + nc_t + (1-n)c_t^* + (1-n)\theta(1 - nz^* - z(1-n))s_t + \ln\alpha \tag{63}$$

$$l_t^{*a} = -\omega(1-\nu)w_t^{*a} + nc_t + (1-n)c_t^* + n\theta(1 - nz^* - z(1-n))s_t \tag{64}$$

Domestic employment depends negatively on the wages of flexible wage setters, positively on an average of Home and Foreign consumption, and through "expenditure switching" effects, positively on the nominal exchange rate. Similarly to Devereux et al. (2003), unanticipated money shocks have both a compositional and a level effect on total world consumption. However, Home employment is effected by the presence of imported intermediates; as some labour is devoted to imports; employment is lower in the Home country as without imported goods. Total world consumption $(nc_t + (1-n)c_t^*)$ should also be calculated by using the pricing formulas, money demand equations.

$$nc_t+(1-n)c_t^* = \frac{\left[\begin{array}{c} nm_t + (1-n)m_t^* - \\ \left[n(1-\alpha n)(1-z^*) + (1-n)n(1-\alpha)(1-z^*) - (1-n)n(1-z))\right] s_t \end{array}\right]}{\rho} \tag{65}$$

Total world consumption depends on weighted money supplies and on the income ("wealth") and substitutioon effects of nominal exchange rate movements. In the next section we show how the equilibrium pass-through, the currency decision of firms in which currency prices are set in advance can be derived by using the results from this and the previous section.

3.3 Determination of equilibrium pass-through

In this section, we put together the results developed in the previous two sections. From Section 3.1. we know that Home firms will choose LCP if $\Psi(\alpha, z, z^*, \sigma_u^2, \sigma^2, \sigma_{u\,\mathrm{u}^*})$›0 where the function $\Psi(\ldots.)$ is defined as:

$$\begin{aligned} \Psi(\alpha, z, z^*, \sigma_u^2, \sigma^2, \sigma_{u\,\mathrm{u}^*}) &= [\alpha cov_{t-1}(s_t, w_t) + (1-\alpha)cov_{t-1}(s_t, p_{ft}) + \alpha(1-\alpha)cov_{t-1}(w_t, p_{ft})] - \\ &\quad - \frac{var_{t-1}(s_t)}{2} \end{aligned}$$

Correspondingly, Foreign firms will use LCP if $\Psi^*(\alpha, z, z^*, \sigma_u^2, \sigma^2, \sigma_{u\,\mathrm{u}^*})$›0, where $\Psi^*(\alpha, z, z^*, \sigma_u^2, \sigma^2, \sigma_{u\,\mathrm{u}^*}) = -cov_{t-1}(s_t, w_t^*) - \frac{var_{t-1}(s_t)}{2}$. The value of $\Psi(\ldots.)$ and $\Psi^*(\ldots.)$ can be calculated by using the general equilibrium model of Section 3.2..

$$var_{t-1}(s_t) = (\frac{1+\frac{\varphi}{r}}{\Gamma})^2(\sigma_u^2 + \sigma_{u^*}^2 - 2\sigma_{u\,\mathrm{u}^*}) \tag{66}$$

The covariance of wages can be similarily calculated as Devereux et al.(2003), the only difference is that here the variance of the nominal exchange rate is different. It is not obvious how the presence of imported intermediates effect the variance of the exchange rate, the relationship depends on the model parameters.

$$cov_{t-1}(w_t, s_t) = \upsilon cov_{t-1}(w_t^a, s_t) \tag{67}$$

$$cov_{t-1}(w_t^*, s_t) = \upsilon cov_{t-1}(w_t^{*a}, s_t) \tag{68}$$

$$cov_{t-1}(w_t^a, s_t) = \frac{1}{1+\psi\omega(1-\upsilon)}\left[\begin{array}{c} (1+\frac{\psi n}{\rho})cov_{t-1}(u_t, s_t) + \psi\frac{1-n}{\rho}cov_{t-1}(u_t^*, s_t) + \\ \psi\left\{\begin{array}{c} (1-n)\theta(1-nz^* - z(1-n)) \\ -\frac{n(1-\alpha n)(1-z^*)+(1-n)n(1-\alpha)(1-z^*)-(1-n)n(1-z))}{\rho} \end{array}\right\} var_{t-1}(s_t) \end{array}\right] \tag{69}$$

$$cov_{t-1}(w_t^{*a}, s_t) = \frac{1}{1+\psi\omega(1-\upsilon)} \left[\begin{array}{c} (1+\frac{\psi(1-n)}{\rho})cov_{t-1}(u_t^*, s_t) + \psi\frac{n}{\rho}cov_{t-1}(u_t, s_t) + \\ -\psi \left\{ \begin{array}{c} n\theta(1-nz^*-z(1-n)) \\ -\frac{n(1-\alpha n)(1-z^*)+(1-n)n(1-\alpha)(1-z^*)-(1-n)n(1-z))}{\rho} \end{array} \right\} var_{t-1}(s_t) \end{array} \right] \tag{70}$$

$$cov_{t-1}(p_{ft}, s_t) = var_{t-1}(s_t) + cov_{t-1}(w_t^*, s_t) \tag{71}$$

$$cov_{t-1}(p_{ft}, w_t) = cov_{t-1}(s_t, w_t) + cov_{t-1}(w_t, w_t^*) \tag{72}$$

We know that wages can be calculated as

$$w_t = \Xi m_t + \Xi^* m_t^*$$

$$w_t^* = \Phi m_t + \Phi^* m_t^*$$

where

$$\Xi = \frac{\nu}{1+\psi\omega(1-\upsilon)}((1+\frac{\psi n}{\rho}) + \psi \left\{ \begin{array}{c} (1-n)\theta(1-nz^*-z(1-n)) \\ -\frac{n(1-\alpha n)(1-z^*)+(1-n)n(1-\alpha)(1-z^*)-(1-n)n(1-z))}{\rho} \end{array} \right\} \frac{1+\frac{\varphi}{r}}{\Gamma}$$

$$\Xi^* = \frac{\nu}{1+\psi\omega(1-\upsilon)}((1+\frac{\psi(1-n)}{\rho}) - \psi \left\{ \begin{array}{c} n\theta(1-nz^*-z(1-n)) \\ -\frac{n(1-\alpha n)(1-z^*)+(1-n)n(1-\alpha)(1-z^*)-(1-n)n(1-z))}{\rho} \end{array} \right\} \frac{1+\frac{\varphi}{r}}{\Gamma}$$

$$\Phi = \frac{\nu}{1+\psi\omega(1-\upsilon)}(\psi\frac{1-n}{\rho} + \psi \left\{ \begin{array}{c} (1-n)\theta(1-nz^*-z(1-n)) \\ -\frac{n(1-\alpha n)(1-z^*)+(1-n)n(1-\alpha)(1-z^*)-(1-n)n(1-z))}{\rho} \end{array} \right\} \frac{1+\frac{\varphi}{r}}{\Gamma}$$

$$\Phi^* = \frac{\nu}{1+\psi\omega(1-\upsilon)}((1+\frac{\psi(1-n)}{\rho}) - \psi \left\{ \begin{array}{c} (1-n)\theta(1-nz^*-z(1-n)) \\ -\frac{n(1-\alpha n)(1-z^*)+(1-n)n(1-\alpha)(1-z^*)-(1-n)n(1-z))}{\rho} \end{array} \right\} \frac{1+\frac{\varphi}{r}}{\Gamma}$$

and hence, the covariance of wages in the two countries are

$$cov_{t-1}(w_t, w_t^*) = \Xi\Phi\sigma_u^2 + \Xi^*\Phi^*\sigma_{u^*}^2 + (\Xi\Phi^* + \Xi^*\Phi)\sigma_{u\,u^*} \tag{73}$$

From the above conditions we can numerically calculate the function $\Psi(\ldots.)$ and $\Psi^*(\ldots.)$. These functions determine the equilibrium share of LCP price setters in both countries. As an extreme case ($\alpha = 1$), the results incorporate that of Devereux et al.(2003). From can analytically calculaet from the above conditions the optimal share of LCP-pricers for both countries ($\overline{z}$ and $\overline{z}^*$). These are functions of all “deep parameters” of the model, except for λ.

$$\overline{z} = \overline{z}(\alpha, n, \theta, r, \psi, \rho, \upsilon, \omega, \sigma_{u\,u^*}, \sigma_{u,}^2\sigma_{u^*}^2)$$

The equilibrium level of LCP-pricing works in the opposite way than to a shock of monetary variance. Increased monetary variance (increased nominal exchange rate variance) will lead to higher probability that firms will follow LCP pricing policies. Hence, pass-through will decrease, and prices will be generally less sensitive to monetary shocks as without having endogenous exchange rate pass-through The full model solution would

4 Results

Throughout this section, we analyse our model for different parameter setups, and compare our results with the baseline model (when $\alpha = 1$). We focus our attention to three questions: how pass-through is related to the monetary regimes, to the country size and to monetary stability. We will show that the presence of imported intermediates can signifficantly modify the answers to the above questions. Throughout this paper, we focus on the export pricing decisions of Home firms. Naturally, pass-through to import prices would also be interesting. Due to the asymmetric treatment of the two countries, i.e. only Home producers use imported intermediates, if one is interested in the determination of import price pass-through, then one should converse the whole model and substitute all the equations on Home variables to their Foreign counterparts, and vica versa. Appendix consists of the parameter setup of different simulations.

4.1 Pass-through in different monetary regimes

As a baseline setup, suppose that the two countries are identical in size ($n = n^* = 0.5$), with similar and independent monetary policies ($\sigma_{u\,\mathrm{u}^*} = 0, \sigma^2_{u,} = 1, \sigma^2_{u^*} = 1$). Assuming a parametrisation described in Appendix, the equilibrium level of LCP price setters in the Home country is a decreasing function of α. On the extreme case, when there is only labour input in both countries production ($\alpha = 1$), a signifficant amount of Home firms will opt for LCP pricing, around 46 per cent of Home exporters will have sticky prices in the target country's currency. Figure 1. shows how α effects this choice. According to the numerical simulations of the model when imported intermediates become more and more important, the share of LCP price setters will increase. A relatively small proportion of imported goods in the production would highly modify the distribution of pricing policies. Around 20 percent of imported goods in the production would force all Home producers to price in the export market currency.

In the case of fully (and credibly) fixed exchange rates, when money supplies in the two countries are perfectly correlated ($\sigma_{u\,\mathrm{u}^*} = 1, \sigma^2_{u,} = 1, \sigma^2_{u^*} = 1$), all Home exporters would price in the foreign currency. Hence, in this model, similarily to Devereux et al. (2003) fixing the exchange rate would decrease the pass-through of exchange rates. For every given α fixing the exchange rate would allways lead to lower pass-through of exchange rate to export prices.

When monetary policies follow dirty floating policies (when there is some positive correlation between money supplies$\sigma_{u\,\mathrm{u}^*} = 1, \sigma^2_{u,} = 1, \sigma^2_{u^*} = 0.25$) the share of LCP price setters will be higher than with independent monetary policies, but lower than in fully fixed exchange rate regimes. However, the "cutoff" value of α, for which all exporters price in foreign currency and passthorugh drops to zero, will be higher than that in the case with independent monetary policies.

One can conclude that taking into account imported intermediates in the production really matters in exchange rate pass-through. Figure 1. shows that the presence of imported intermediates tends to bias the effects of monetary policy in the direction towards the case of fixed exchange rates. This is straitghtforward: suppose that Home exporters only use imported intermediates ($\alpha = 0$), one can easily conclude that in this case nominal exchange rate would not have any effect on exports, and hence pass-through will be zero.

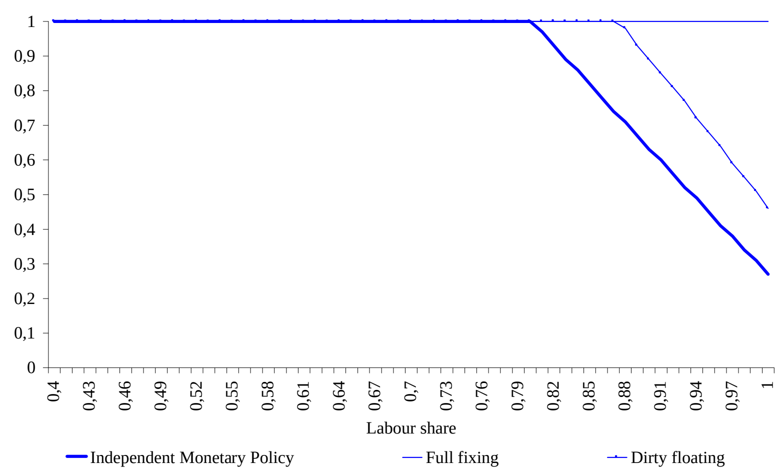

Figure 1. Share of Home LCP exporters in different exchange rate regimes

4.2 Effects of country size on pass-through

Another important issue in the determinants of pass-through is naturally the (relative) size of the countries. One would expect that an exporter in a relatively small country would mostly price its products in the larger countries currency. This is generally the case in our model, as well. Compared to the baseline setup where the two countries are equal in size (and follow independent monetary policies), our simulations show that for the "cutoff" α, for which all exporters follow LCP pricing policies, would increase by much (in the case when Foreign country is nine times larger than Home). Hence, in small countries, the presence of imported intermediates does not signifficantly change the results of the benchmark Devereux et al. (2003) model.

For large Home country, the converse holds. Figure 2. shows that in this case even if there are no imported intermediates in the production, share of LCP price-setters will be almost zero. However, the role of imported intermediates is very signifficant in this case. Even a relatively small share imported goods would result in a distribution of firms, which is closer to that experienced in the case of equal sized countries. For around 50 percent of imported goods in the production will make the majority of the large countries exporters to behave very similar to those in smaller countries. They will be more and more hedged against exchange rate fluctuations, and thus will opt for LCP pricing policies more frequently.

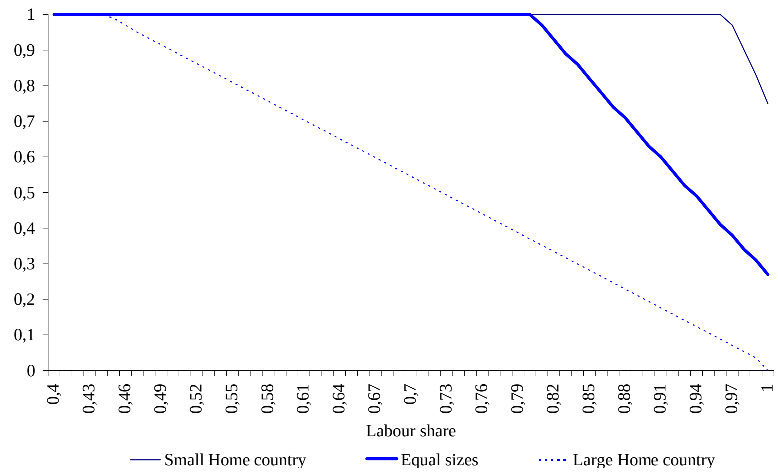

Figure 2. Effect of Country Size on the Share of Home LCP firms

4.3 Effects of monetary stability on pass-through

Figure 3. shows how monetary variance effects the choice of currency. In all cases, we assumed independent monetary policies ($\sigma_{u\,\mathrm{u}^*} = 0$) and countries of equal size. As a baseline scenario, we set the variances of the money supplies to be equal. We have simulated what would happen if monetary variance would increase to a level which is two times higher than in the Foreign country. It can be seen, that increased monetary variance works in the direction similar to fixing the exchange rate, the share of LCP exporters increase for every level of alfa. Opposite effects can be detected with increased Foreign monetary variance: the share of LCP prices drop, as the increased variance of the nominal exchange rate would not cushion Home exporters for higher exchange rate risk. However, in this case, the presence of imported intermediates can highly modify the picture. Even for a relatively low share of imported goods in the production makes firms more hedged against higher exchange rate fluctuations. The "cutoff" α, for which all Home exporters will price by LCP, of around 20 per cent in this parameter combination would lead to LCP pricing.

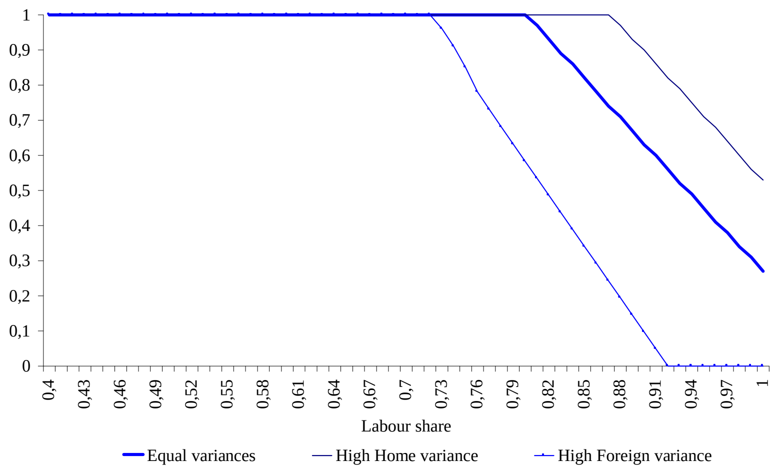

Figure 3. Effect of Monetary Variance on the Share of Home LCP firms

Summing up the three simulation presented above, our model incorporates the benchmark Devereux et al. (2003) model for $\alpha = 1$. However, the behaviour of firms can be signifficantly changed when we introduce imported goods in the production. For small countries, for fixed exchange rates and for relatively high Home monetary instability, our model does not really modify the results of the model without imported intermediates. However, the likelihood that exporters even in a large country, or in a country with stable monetary policy or with highly independent and (inward looking) monetary policy, local currency pricing policies can be markedly increased when production requires imported intermediates.

5 Conclusions

In this paper, we developed a model for endogenous exchange rate pass-through when imports do not only serve as consumption goods, but as inputs for production. First, we derived the conditions under which firms choose in which currency they set their price (in which currency they are „sticky"). Imported goods modify the conditions developed by Devereux et al. (2003), in the sense that they might also serve as a natural hedge against nominal exchange rate fluctuations.

As a second step, a general equilibrium model with sticky prices and wages was set up, where Home production requires input of imported goods, as well. Given, that firms set their prices in advance when the state of the world is known, there is an expenditure switching effect of nominal exchange rate fluctuations.

As a third step, the general equilibrium model and the conditions on the determination of firms' pricing policies were put together. This lead us to calculate the optimal share of LCP price-setters. Our simulations has shown that although the benchmark model of Deveruex et al. (2003) remains valid when there are no imported goods in the production function, incorporating them largely changes the results on firms' pricing strategies. We have found that for any given level of share of imported intermediates, the conclusion of the benchmark model still hold: e.g. fixing the exchange rate, monetary instability and small country size decreases the pass-through of exchange rate to export prices. The model with imported goods in the production function gives similar results to the benchmark model for small countries, fixed exchange rates and relatively high Home monetary instability. However, exporters in a large country, or in countries with stable domestic monetary policy, or where monetary policy is highly independent of other countries' policies, the share of local currency pricing policies increases if production requires imported intermediates compared to the benchmark model.

We found that the presence of imported intermediates might alter the optimal monetary policy implications of Devereux et al. (2003). Though their conclusions remain valid in the case when there are no imported goods in production, the exchange rate pass-through might be sensitive to the import content of production. Optimal monetary policy should also focus on imported inflation in countries with flexible exchange rates or in countries with relatively large monetary variability. Hence, there might not necessarily be a conflict between the two views: in some circumstances inward-looking (which only focuses on stabilising domestic inflation) and in other circumstances outward looking (which focuses on both stabilising domestic and imported inflation) monetary policy will be optimal. The choice between different monetary strategies depends on the importance of imported intermediates in production.

References

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

[2] Blanchard, O.and Kiyotaki, N. (1987) "Monopolistic Competition and the Effects of Aggregate Demand", *American Economic Review*, 77, pp.: 647-666.

[3] Devereux, M. and Engel, Ch. (2000) "Monetary Policy in the Open Economy Revisited: Price Setting and Exchange Rate Flexibility", *National Bureau of Economic Research Working Paper*, No. 7665.

[4] Devereux, M., Engel, Ch. and Storgaard, P. (2003) "Endogenous Exchange Rate Pass-through when Nominal Prices are Set in Advance", *National Bureau of Economic Research Working Paper*, No. 9543.

[5] Lane, Ph. (2000) "The New Open Economy Macroeconomics: A Survey", *Journal of International Economics*, 54, pp.: 235-266.

[6] McCallum, B. and Nelson, E. (2001) "Monetary Policy for an Open Economy: An Alternative Framework with Optimizing Agents and Sticky Prices", *National Bureau of Economic Research Working Paper*, No. 8175.

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

[8] Obstfeld, M. and Rogoff, K. (2000) "New Directions for Stochastic Open Economy Models", *Journal of International Economics*, 50, pp.: 117-153.

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

6 Appendix: Parameter setup in different simulations

	Baseline	Small Home	Large Home	Fixed exchange rate	Dirty floating	High Home monetary variance	High Foreign monetary variance
n	0.5	0.1	0.9	0.5	0.5	0.5	0.5
σ_u^2	1	1	1	1	1	2	1
σ_u^2	1	1	1	1	1	1	2
$\sigma_{u\,\mathrm{u}^*}$	0	0	0	1	0.25	0	0
ψ	1	1	1	1	1	1	1
ρ	1.25	1.25	1.25	1.25	1.25	1.25	1.25
υ	0.75	0.75	0.75	0.75	0.75	0.75	0.75
ω	1.5	1.5	1.5	1.5	1.5	1.5	1.5
θ	1	1	1	1	1	1	1
r	0.1	0.1	0.1	0.1	0.1	0.1	0.1