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**Working Paper**

## Price rigidity, the mark-up and the dynamics of the current account

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Price rigidity,  
the mark-up  
and the dynamics  
of the current account

Giovanni Lombardo

Discussion paper 14/02  
Economic Research Centre  
of the Deutsche Bundesbank

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## **Abstract**

This paper shows that the degree of competition affects the current account response to nominal shocks. The mechanism hinges on the relationship between the mark-up and the degree of real rigidity of prices. In a model with intermediate goods, the degree of real rigidity increases in the markup. A weaker response of prices to nominal shocks strengthens the “expenditure switching” effect of the devaluation to the benefit of the current account. We first analyse the relationship between the mark-up and the real rigidity in a simple closed economy model. We then show numerically how the mark-up can affect the response of the current account to monetary shocks.

**Keywords:** Current account; mark-up; monopolistic competition; persistence; real rigidity; nominal rigidity.

**JEL:** F32, E32

## **Zusammenfassung**

Der vorliegende Beitrag zeigt, dass der Grad der Wettbewerbsintensität die Reaktion der Leistungsbilanz auf nominale Schocks beeinflusst. Entscheidend hierfür ist der Zusammenhang zwischen dem Mark-up und der realen Rigidität der Preise. In einem Modell mit Zwischenprodukten nimmt die reale Rigidität mit dem Mark-up zu. Bei einer schwächeren Reaktion der Preise auf nominale Schocks führt eine Abwertung zu einer stärkeren Verschiebung der Ausgaben mit positiven Auswirkungen auf die Leistungsbilanz. Zunächst wird das Verhältnis zwischen dem Mark-up und der realen Rigidität in einem einfachen Modell einer geschlossenen Volkswirtschaft untersucht. Anschließend wird numerisch dargestellt, wie der Mark-up die Reaktion der Leistungsbilanz auf monetäre Schocks beeinflussen kann.

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# Price rigidity, the mark-up and the dynamics of the current account<sup>1</sup>

## 1 Introduction

Many studies have addressed the macroeconomic consequences of firm-level price rigidities. This New Keynesian literature has highlighted the importance of the market structure - degree and type of imperfect competition - for an economy's response to nominal shocks. Two significant findings are that imperfect competition alone is insufficient to undermine the neutrality of money and that endogenous price stickiness, or "real rigidity" of prices, is typically required for the real effects of nominal disturbances to be reasonably persistent: a point that has been particularly emphasized by Ball and Romer (1990) and Kimball (1995). They show that the sensitivity of a firm's optimal relative price to aggregate shocks, i.e. the degree of real rigidity, is a crucial factor in the transmission of monetary perturbations. The role played by this sensitivity differs according to the type of nominal rigidities assumed. In a model of "menu costs" (*à la* Mankiw, 1985) or of limited rationality (*à la* Akerlof and Yellen, 1985) reduced sensitivity implies a reduced *incentive* to adjust

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<sup>1</sup>Forthcoming in the *Canadian Journal of Economics*. An earlier version of this paper was written while the author was a lecturer in the Department of Economics, Trinity College Dublin, Ireland. The author is indebted to the people at Trinity College for their kind help. The author also wishes to thank the following people for their help and useful comments: Philip Lane, Stephanie Schmitt-Grohé, Michael Devereux, the participants at a seminar in the Department of Economics, University of Trento and those at a seminar in the Department of Economics, NUI-Maynooth, Ireland. Some of the material in this paper appeared in an earlier working paper presented at the Annual Conference of the European Economic Association, 2000, and at the Macro, Money and Finance Conference, 2000. The views expressed in the paper are those of the author and not necessarily those of the Bundesbank.



prices in response to aggregate nominal demand shocks. In models with a partial adjustment of prices (*à la* Calvo, 1983) or with a staggered price setting (*à la* Taylor 1980), reduced sensitivity implies only a limited response of the aggregate price level.

The main objective of later macroeconomic research on this topic was to address “persistence”.<sup>2</sup> In this respect, the distinction between “nominal rigidities” (e.g. price contract length) and “real rigidity” (optimal price responsiveness to aggregate shocks) has proved particularly useful.<sup>3</sup> Indeed, one of the major contributions of microfounded models of price stickiness, as opposed to old Keynesian models, can be seen in the ability of these models to highlight various factors that could increase the stickiness of prices beyond the length of the “price contracts”. A number of these factors have been discussed in recent papers, e.g. countercyclical mark-ups (Ball and Romer (1990), Kiley (1997) and Bergin and Feenstra (2000)), intermediate goods (Basu (1995), Bergin and Feenstra (2000) and Barro and Tenreyro (2000)), and the degree of competition in equilibrium (Kimball (1995) and Romer (1996, ch 6)).

This study describes the contribution of steady-state competition to “persistence” and hence to the current account response to nominal shocks. We show how the degree of competition can affect the current account response to monetary shocks through the demand for production factors in a model with composite demand *à la* Galí (1994, 1996) and intermediate goods in production *à la* Basu (1995).

Since the seminal work of Obstfeld and Rogoff (1995, 1996) there has been a proliferation of open economy models with nominal rigidities.<sup>4</sup> Some of these models address the implications of nominal rigidities for the current account

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<sup>2</sup>See, for example, Chari et al. (2000), Erceg (1997) and Bergin and Feenstra (1999).

<sup>3</sup>A clear discussion is given in Romer (1996, ch 6).

<sup>4</sup>For a recent survey of the New Open Economy literature see Lane (2000).

dynamics. For example, Lane (2001) considers the current account response in a two-country, two-sector model with price rigidities. In his model, the current account response depends on both the intertemporal elasticity of substitution in consumption and the degree of substitutability between imported and domestically produced goods. Lane also provides some empirical support for the positive relationship between the current account and monetary shocks.<sup>5</sup> Lombardo (1998) also shows that the intertemporal elasticity of substitution can affect the trade balance dynamics in this class of models, besides the more traditional Marshall-Lerner condition.<sup>6</sup> Devereux (2001) looks at the effects of a devaluation on the current account. He finds that the Marshall-Lerner condition governs the current account response to a monetary shock when prices are set in the currency of the producer. When prices are set in the currency of the buyer (pricing to market), the intertemporal elasticity of substitution also plays an important role. By and large, therefore, there is some consensus about the importance of the wealth effect (measured by the intertemporal elasticity of substitution) for the adjustment of the foreign trade balance. Nevertheless, none of these works has considered the role of the degree of competition in the current account response to shocks. This paper sets out to fill that gap.<sup>7</sup>

Our main result can be summarised as follows. Assuming that there is some degree of substitutability between intermediate goods and other production factors, the steady-state level of the mark-up will be inversely related to the share of intermediate goods used in production. This result has also been

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<sup>5</sup>Recently Giuliadori (2001) has extended Lane's work to 15 OECD countries, with similar results.

<sup>6</sup>This condition states that the current account improves upon a devaluation if the sum of the elasticity of import and export is larger than one (Krugman and Obstfeld, 1997).

<sup>7</sup>Andersen and Beier (1999) also point out that current research has failed to highlight the importance of the relationship between "persistence" and the current account.

pointed out in a recent paper by Barro and Tenreyro (2000) in a model that produces a countercyclical mark-up. Since the production of intermediate goods competes with the production of final goods for the allocation of scarce resources, a lower share of intermediates implies lower production costs and hence more real rigidity. In a 2-country model with flexible exchange rates, when a monetary shock hits one of the countries, the “expenditure switching” that follows is larger the smaller the price increase in the devaluing country. Therefore, the current account is more likely to improve in the event of a positive monetary shock (devaluation) if there is less competition.

The rest of this study is organised as follows. Section 2 builds a simple closed economy model with composite demand, an “input-output” production structure and monopolistic competition.<sup>8</sup> This section shows analytically the mechanism through which the mark-up can affect the price-level response to monetary shocks. Section 3 expands the model into a two-country version as a means of linking the degree of competition to the current account response. This version of the model also introduces capital accumulation. The linearised solution and the simulations are discussed in section 4. Section 5 concludes.

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<sup>8</sup>By “input-output” production we refer to the production structure described in Basu (1995). Basu contrasts this structure with “in-line” production. The former is such that all goods produced enter the production process of all the goods produced in the economy. The latter is such that final goods do not enter the production process of intermediate goods. The Basu set-up is widely used in this type of model (see, for example, Bergin and Feenstra (2000) and Barro and Tenreyro (2000)).

## 2 Composite demand and price response in a closed economy

As stated in the introduction, the relationship between the degree of competition and the current account response to monetary shocks passes through the “real rigidity” effect on the aggregate price adjustment. In this section we isolate this price effect by solving a closed economy model based on the same structure of the open economy version presented below.

To this end we use a reduced-form model. The behavioural equations are typical of models of monopolistic competition with intermediate goods in production and Taylor nominal price contracts. The underlying agents’ problem from which they stem is very similar to that which is presented in the open economy sections below.

### 2.1 Households

Households have preferences over consumption of a wide range of differentiated goods and over the amount of time dedicated to labour. There is a continuum of households, which we index on the unitary segment. The demand for consumption goods of type  $j$  is defined as

$$c_j = \left(\frac{p_j}{P}\right)^{-\theta} C, \quad (1)$$

where  $p_j$  is the price of item  $j$ ,  $P$  is the aggregate price level,  $\theta > 1$  is the absolute value of the elasticity of substitution between goods, and  $C$  denotes real expenditure.

We assume that individuals are “cash-constrained” so that

$$C = v \frac{M}{P}, \quad (2)$$

where  $v$  is a positive constant and  $M$  is the money stock.

Households also supply labour according to a supply function defined as<sup>9</sup>

$$L = \left( \frac{W}{P} \right)^\zeta,$$

where  $L$  is the total amount of labour supplied,  $\zeta > 0$  is the elasticity of labour supply and  $W$  is the nominal wage rate.

## 2.2 Firms

There are many monopolistically competitive firms producing a range of partially substitutable goods. Firms are indexed on the continuous segment of measure 1. The products are demanded by households as consumer goods and by all firms as intermediate goods. Following Galí (1994, 1996), we assume that goods are sold at the same price whatever their final destination. The demand for intermediate goods (denoted by  $z$ ) is similar to the demand for final goods except for the elasticity, which in principle can differ from  $\theta$ . In this section we assume identical elasticities, while different elasticities are considered in the next section.<sup>10</sup> Hence the demand for intermediate goods is similar to that for consumer goods (equation (1)).

The total composite demand faced by firm  $j$  is therefore

$$D_j = z_j + c_j = \left( \frac{p_j}{P} \right)^{-\theta} (C + Z),$$

where  $Z$  is the total real demand for intermediate goods.

The elasticity of this demand with respect to the relative price is simply  $\theta$ , so that the equilibrium mark-up of prices over marginal cost is  $\mu = \theta(\theta - 1)^{-1}$ .

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<sup>9</sup>Contrary to the open economy model we assume in this section that labour supply is not a function of income.

<sup>10</sup>Identical elasticities are assumed in Basu (1995), Bergin and Feenstra (2000) and Barro and Tenreyro (2000).

Firms produce according to a Cobb-Douglas production function ( $Y_j = Z_j^\alpha L_j^{1-\alpha}$ ).

We assume here that firms can be divided in two cohorts of equal size, according to the timing of price-setting. They set prices for two consecutive periods in a staggered fashion, *à la* Taylor (1980). When firms set prices, they do so in order to maximise profits for two consecutive periods. All firms within the same group set identical prices. In any one period the aggregate price level is simply the average of the prices of the two groups, i.e.  $P_t = \frac{1}{2} (p_t + p_{t-1})$ .

## 2.3 Solution

To solve the model we linearise it around the symmetric steady state.

We first note that profit maximisation implies the following conditional factor demand for intermediate goods

$$P_t = \frac{p_{j,t}}{\mu} \alpha \frac{Y_t}{Z_t}, \quad (3)$$

which in equilibrium (ss) yields

$$\frac{Z_{ss}}{Y_{ss}} = \frac{\alpha}{\mu}. \quad (4)$$

This tells us that the equilibrium share of intermediate goods in output is inversely related to the mark-up. This is indeed a standard result: the larger the mark-up the smaller the share of factors of production in total output. In the specific case of intermediate goods this is tantamount to saying that the demand for intermediate goods decreases in the mark-up.

The linearised composite demand faced by each firm is

$$\tilde{D}_{j,t} = -\theta \left( \tilde{p}_{j,t} - \tilde{P}_t \right) + \frac{\alpha}{\mu} \tilde{Z}_t + \left( 1 - \frac{\alpha}{\mu} \right) \tilde{C}_t; \quad j = \{1, 2\}. \quad (5)$$

The aggregate demand is therefore  $\tilde{D}_t = \alpha\mu^{-1}\tilde{Z}_t + (1 - \alpha\mu^{-1})\tilde{C}_t$ .

Given our production function, the marginal cost is

$$\widetilde{MC} = \tilde{P} + (1 - \alpha) (\tilde{W} - \tilde{P}) , \quad (6)$$

so that the optimal demand for intermediate goods can be expressed as

$$\tilde{Z}_t = (1 - \alpha) (\tilde{W}_t - \tilde{P}_t) + \tilde{D}_t . \quad (7)$$

We can obtain a real wage equation by solving for the labour market equilibrium.

The labour supply is simply  $\tilde{L}_{s,t} = \zeta (\tilde{W}_t - \tilde{P}_t)$ , whereas the conditional demand for labour is  $\tilde{L}_{d,t} = -\alpha (\tilde{W}_t - \tilde{P}_t) + \tilde{D}_t$ . Equating demand and supply and solving for the real wage, we obtain

$$\tilde{W}_t - \tilde{P}_t = (\zeta + \alpha)^{-1} \tilde{D}_t . \quad (8)$$

Using equation (8) in equation (7) and the definition of aggregate demand, we can express the demand for intermediate goods as a function of the demand for final goods, i.e.

$$\tilde{Z}_t = \psi \tilde{C}_t , \quad (9)$$

where  $\psi = (1 - \alpha\mu^{-1}) [(\alpha + \zeta) (1 + \zeta)^{-1} - \alpha\mu^{-1}]^{-1}$  so that  $\psi > 1$ .

Using equations (2), (8), and (9) in the marginal cost equation (6) we obtain

$$\widetilde{MC}_t = \Phi \widetilde{M}_t + (1 - \Phi) \tilde{P}_t , \quad (10)$$

where  $\Phi = (1 - \alpha) [\zeta + \alpha (\mu - 1) (\mu - \alpha)^{-1}]^{-1} > 0$ .

It is immediately evident that  $\Phi$  is decreasing in  $\mu$ . A large mark-up implies a reduced sensitivity of the marginal cost to a monetary shock, when prices do not adjust completely. This can also be seen in the relation between the demand for intermediate goods and the demand for final goods (equation (9)).

Since  $\psi$  is decreasing in  $\mu$ , a higher degree of imperfect competition induces a smaller use of intermediate goods for any unit of output and hence reduces the pressure on production costs. In the following it will be useful to note that  $\psi - 1 = \Phi\mu(\mu - \alpha)^{-1}$ .

Moreover, as  $\alpha$  tends to zero, the marginal cost becomes independent of the degree of competition, boiling down to  $\zeta^{-1}$ : the higher the elasticity of substitution of labour the higher the real rigidity.

To demonstrate the relationship between the degree of competition (the mark-up) and persistence, let us first assume that firms determine prices as an arithmetic average of the optimal price in two consecutive periods. That is  $\tilde{p}_t = 0.5 \left( \widetilde{MC}_t + \mathcal{E}(\widetilde{MC}_{t+1}) \right)$ , where  $\mathcal{E}$  denotes the expectation operator. By substituting equation (10) in this expression we obtain

$$\tilde{p}_t = 0.5 \left\{ \left[ \Phi \widetilde{M}_t + (1 - \Phi) \tilde{P}_t \right] + \mathcal{E} \left[ \Phi \widetilde{M}_{t+1} + (1 - \Phi) \tilde{P}_{t+1} \right] \right\} . \quad (11)$$

For the sake of simplicity we also assume that the money stock is a random walk, i.e.  $M_t = M_{t-1} + u_t$ , where  $u_t$  is white noise. Using the definition of the aggregate price, the solution of equation (11) is then <sup>11</sup>

$$\tilde{p}_t = \lambda \tilde{p}_{t-1} + (1 - \lambda) \widetilde{M}_t , \quad (12)$$

where  $\lambda = \left( 1 - \sqrt{\Phi} \right) \left( 1 + \sqrt{\Phi} \right)^{-1}$  so that  $|\lambda| < 1$ .

From equation (12) we can see that the impact of a monetary shock on the price level increases in  $\lambda$ . This will have important consequences in the open economy model: the current account response to nominal shocks will depend on the size of this parameter. Furthermore, if we are willing to assume that prices do not oscillate around their long-run level, i.e.  $0 < \lambda < 1$ , then the

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<sup>11</sup>Solving equation (11) is straightforward. See, for example, Romer (1996, ch 6, section 6.5).



larger  $\lambda$  is, the longer it will take for the price to converge to its long run-level.<sup>12</sup> Note that  $\Phi$  is decreasing in  $\mu$  while  $\lambda$  is decreasing in  $\Phi$ . A larger mark-up implies a weaker impact of the monetary shock on the price level as well as a more persistent deviation of the price level from its long-run level.

In the open economy model discussed in the following sections, the response of the current account depends on the amount of “expenditure switching” and hence on the response of the price level to the nominal shock. We can therefore say that the response of the current account is linked to the amount of persistence in the economy.<sup>13</sup> This claim is substantiated in the following section.

### 3 A two-country model

The model we use in this and the following sections is a New Open Economy model. It is a two-country model with imperfect competition and Calvo (1983) price-contracts.

We now use Calvo contracts for computational convenience. Calvo contracts give much smoother price responses and generate a more parsimonious model than the Taylor assumption.

In this section we assume that the production technology requires the use of all the goods produced internationally, although there is a certain degree of substitutability among them. We also introduce capital accumulation. This

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<sup>12</sup>Note that in the long-run, the change in the price level will be identical to the change in the money stock: money is neutral in the long-run.

<sup>13</sup>In theory,  $\Phi$  could be larger than one. In this case the price level would respond more than proportionally to the monetary shock and it would then oscillate towards its long run value. Since this is not considered to be a good description of reality, it is typically assumed that  $\Phi$  lies between zero and one.

provides an extra dynamic source to the model as well as an important source of production costs. We are thus able to assess whether the effect of the degree of competition on the current account is still detectable in a more complete setting with capital accumulation.

### 3.1 Households

We assume that there are only two countries in the world, which we name “home” and “foreign”. The world population has measure 1. A fraction  $n$  of the world population lives in the home country, while the fraction  $(1 - n)$  lives in the foreign country. All individuals within a country are identical.

Households have preferences over consumer goods, real balances and labour supply. Households consume all types of goods produced in the two countries. We assume that the variety of goods produced in the home country is of measure  $n$  and that the variety produced in the foreign country is of measure  $(1 - n)$ . These various consumer goods are aggregated by the following CES function (for the home country)

$$\begin{aligned} C &= \left\{ n^{\frac{1}{\theta}} C_h^{\frac{\theta-1}{\theta}} + (1-n)^{\frac{1}{\theta}} C_f^{\frac{\theta-1}{\theta}} \right\}^{\frac{\theta}{\theta-1}} \\ C_h &= \left\{ n^{-\frac{1}{\omega}} \int_0^n c_{h,j}^{\frac{\omega-1}{\omega}} dj \right\}^{\frac{\omega}{\omega-1}} \\ C_f &= \left\{ (1-n)^{-\frac{1}{\omega}} \int_n^1 c_{f,j}^{\frac{\omega-1}{\omega}} dj \right\}^{\frac{\omega}{\omega-1}}, \end{aligned} \tag{13}$$

where  $c_h$  and  $c_f$  represent home and foreign consumer goods, respectively.  $\theta > 0$  is the elasticity of substitution between goods produced domestically and imported goods.  $\omega > 0$  is the elasticity of substitution between goods produced within the same country (both in absolute values). Both elasticities are assumed to be identical across countries. The foreign country has, *mutatis mutandis*, an identical aggregation function. The price of the consumption

index  $C$  is

$$P = \left( nP_h^{1-\theta} + (1-n)(EP_f)^{1-\theta} \right)^{\frac{1}{1-\theta}}, \quad (14)$$

where

$$P_h = \left( \frac{1}{n} \int_0^n p_i^{1-\omega} di \right)^{\frac{1}{1-\omega}} \quad (15)$$

and

$$P_f = \left( \frac{1}{1-n} \int_n^1 q_j^{1-\omega} dj \right)^{\frac{1}{1-\omega}}, \quad (16)$$

where  $E$  stands for the price of the foreign currency in terms of the home currency (the nominal exchange rate),  $p_j$  is the price of item  $c_{h,j}$  and  $q_j$  is the price of item  $c_{f,j}$  expressed in foreign currency.

Markets are not segmented internationally with the result that the *law of one price* holds. Since all goods are traded *purchasing power parity* also holds.

The demand functions for consumer goods take the following form (for any item  $i$ )

$$c_i = \left( \frac{p_i}{P_h} \right)^{-\omega} \left( \frac{P_h}{P} \right)^{-\theta} C^W, \quad (17)$$

where the superscript  $^W$  stands for world aggregate.

Households solve the following problem

$$\max_{C, \frac{M}{P}, l} \sum_{s=t}^{\infty} \beta^{t-s} \left[ \frac{C_s^{1-\sigma}}{1-\sigma} + \frac{\chi}{1-\phi} \left( \frac{M_s}{P_s} \right)^{1-\phi} - \frac{\zeta}{1+\zeta} l_s^{\frac{1+\zeta}{\zeta}} \right] \quad (18)$$

$$s.t. \quad M_s + B_{s+1} + F_{s+1} + P_{I,s}X_s = w_s l_s + P_{k,s}K_s + M_{s-1} + \Pi_s + \quad (19)$$

$$+ (1 + i_s) B_s + (1 + \tau_s) F_s - P_s C_s - T_s$$

$$X_s = I_s + \frac{\kappa}{2} \frac{I_s^2}{K_s} \quad (20)$$

$$K_{s+1} = I_s + (1 - d) K_s \quad (21)$$

$$s = t \dots \infty ,$$

where  $K$  is the capital stock,  $l_s$  is the labour supply,  $C$  is the consumption index defined by equation (13),  $M$  is money,  $B$  is a nominal bond, in home currency, which represents the debt/credit stance of home households with respect to foreign households,  $F$  is a domestic bond with zero aggregate net supply,  $P$  is the consumer price index as defined by equation (14),  $w$  is the nominal wage,  $\Pi$  is the sum of profit shares from all firms,  $T$  is tax (transfer) paid by (to) the individual,  $i$  is the (consumption based) nominal return on foreign assets and  $\tau$  is the nominal return on domestic assets. It is assumed that  $\phi$  and  $\sigma$  are positive; so is the elasticity of labour supply  $\zeta$ . Finally  $\beta = (1 + \delta)^{-1}$ , where  $\delta$  (bounded between zero and one) is the rate of time preference.  $X$  is total investment, i.e. gross investment plus the installation cost.  $\kappa$  is a positive constant.<sup>14</sup>

Gross investment  $I$  is a CES aggregate of all types of goods produced in the world, similar to equation (13). As for the investment aggregator we denote by  $\hat{\omega}$  the elasticity of substitution between goods produced within the same country and by  $\eta$  the elasticity of substitution between imported and domestically produced goods. The price indexes for this aggregator are similar to those for the consumer goods aggregator (equations (14)-(16)).

Labour is internationally immobile. Households lend capital only to do-

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<sup>14</sup>An alternative would be to make firms own the capital stock directly. This would clearly not alter our results. Our structure can be found, for example, in Chari *et al.* (2000)

mestic firms.

The foreign relations are simply a duplicate of all the equations applicable to the home households, except that to convert home into foreign prices we must apply the reverse exchange rate  $E^{-1}$ . The foreign variables are indicated by an asterisk. Notice, in particular, that the foreign price indexes are denoted by  $P^*$  and  $P_Z^*$  rather than by  $Q$  etc.

Our assumption regarding the household problem is widely used in New Open Economy macro models (see Obstfeld and Rogoff, 1996). One of the features of this set-up is that it implies incomplete asset markets. A well-known consequence is that these models display non-stationary dynamics, so that linearising the model around the initial steady state could yield a poor approximation of the non-linear model. A great many papers have dealt with these issues in the recent literature.<sup>15</sup>

Generally, this problem does not affect the predictions produced by the models. As we will show, this also applies to our model. There are at least two ways in which the unit root in the dynamics of our economy can be eliminated.<sup>16</sup> One consists of introducing an endogenous discount factor (e.g. Devereux and Shi (1991) and Schmitt-Grohé (1998)). The other amounts to imposing a “premium” on the asset return which is proportional to the outstanding stock of bonds. In other words there is an upward sloping supply curve for funds. Schmitt-Grohé and Uribe (2000) (SGU hereafter) use the latter technique in a small open economy model.

In our model we use a modified version of the latter solution. In a small open economy model the SGU solution is equivalent to introducing an asym-

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<sup>15</sup>These include Devereux and Shi (1991), Schmitt-Grohé (1998), Schmitt-Grohé and Uribe (2000) and Letendre (2000).

<sup>16</sup>These were kindly suggested to the author by Stephanie Schmitt-Grohé and Mick Devereux.

metry into the return on foreign assets faced by the domestic economy as opposed to the international return. In a two-country model this implies that the interest rate on bonds paid by the debtor differs from the interest rate received by the creditor. Various explanations can be given for the existence of this kind of asymmetry.<sup>17</sup> Nevertheless, since this type of asymmetry has no microfoundation in this model, it is best explained by the fact that it eliminates the nonstationarity. This is the argument prevailing in the literature and the one we prefer. We also follow the literature in calibrating such an asymmetry so to minimise its effects on the dynamics of our model.

This financial friction enables us to check whether the sensitivity of the current account with respect to the degree of competition is dependent on the non-stationarity of the current account. The simulation results given below demonstrate clearly that the current account response to a monetary shock is sensitive to the degree of competition, irrespective of whether there is or not a unit root in the foreign asset position. The intuition behind this result is that the long-run asset position can, at most, affect current expenditure *levels* (via intertemporal substitution and consumption smoothing), but does not affect the current *expenditure switching*. It is the latter and not the former that determines the sign of the current account response in our symmetric model. This presumption is confirmed by sensitivity analysis (not shown), where the degree of intertemporal substitution as well as the steady-state asset return are increased one hundred fold. Given these parameter values, there was no change in the qualitative response of the current account.

Let us define the home return on domestic assets as

$$i_t = i_t^W \mathcal{P}(B_t) , \quad (22)$$

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<sup>17</sup>For example a fee (or tax etc) that varies across countries and that is proportional to their foreign asset position.

where  $i^W$  is the nominal return on bonds ex-premium and where  $\mathcal{P}(B_t)$  is the premium. We assume that the premium is positive and that  $\mathcal{P}(0) = 1$ .

By analogy, the foreign return on foreign assets is  $i_t^* = i_t^W \mathcal{P}^*(B_t^*)$ , where  $\mathcal{P}^*(B_t^*)$  is the positive foreign premium, such that  $\mathcal{P}^*(0) = 1$ .

The first order conditions of the household problem are the usual in this class of models, except for the optimal interest rate. Having introduced an asymmetric premium, the equilibrium interest rate is

$$(1 + \tau_{t+1}) = (1 + i_{t+1}) + \mathcal{P}'(B_{t+1}) B_{t+1} , \quad (23)$$

so that

$$(1 + \tau_{t+1}) = 1 + i_{t+1}^W (\mathcal{P}(B_{t+1}) + \mathcal{P}'(B_{t+1}) B_{t+1}) . \quad (24)$$

Similar conditions hold for the foreign household. In particular, it is worth noting that the following applies to the foreign country

$$(1 + \tau_{t+1}^*) E_{t+1} = [1 + i_{t+1}^W (\mathcal{P}^*(B_{t+1}^*) + \mathcal{P}^{*'}(B_{t+1}^*) B_{t+1}^*)] E_t , \quad (25)$$

where  $B_t^*$  is the (foreign) bond holding of the foreign household in home currency units.

For the sake of simplicity we assume that the two countries are of equal size, so that  $B_t = -B_t^*$ . Then, isolating  $i_{t+1}^W$  from equation (24) and replacing it in equation (25) yields

$$(1 + \tau_{t+1}^*) \frac{E_{t+1}}{E_t} = 1 + \tau_{t+1} \left[ \frac{\mathcal{P}^*(B_{t+1}^*) + \mathcal{P}^{*'}(B_{t+1}^*) B_{t+1}^*}{\mathcal{P}(B_{t+1}) + \mathcal{P}'(B_{t+1}) B_{t+1}} \right] . \quad (26)$$

Equation (26) is a modified Uncovered Interest Parity (UIP) condition. The term in square brackets on the right-hand side of equation (26) measures the distortion caused by the premium. This distortion disappears when there are zero foreign bond holdings. There would also be no distortion if the premium were symmetric across countries.

For our model to yield a stable solution we must impose the following condition on the premium faced by the two countries

$$\mathcal{P}^{*'}(0) + \mathcal{P}'(0) < 0 . \quad (27)$$

Condition (27) basically states that the change in the return faced by the debtor country (adjusted for the exchange rate variation) is larger than the change in the return faced by the creditor country. To see how condition (27) works the log-linearised UIP is derived, i.e.

$$\frac{\delta}{\delta + 1} \tilde{\tau}_{t+1}^* = \tilde{E}_t - \tilde{E}_{t+1} + \frac{\delta}{\delta + 1} \tilde{\tau}_{t+1} - 2P_0C_0 [\mathcal{P}^{*'}(0) + \mathcal{P}'(0)] \tilde{B}_{t+1} . \quad (28)$$

So, for example, leaving aside the exchange rate, if the home country becomes a net creditor ( $\tilde{B}_{t+1} > 0$ ), its interest rate will go up by less than the increase in the foreign interest rate.

In order to reduce the distortion of the ad hoc premium imposed in the model, and following Schmitt-Grohé and Uribe (2000), we calibrate the coefficient on bonds in equation (28), so that, virtually, the UIP still holds.

### 3.2 Money supply.

Money supply innovations are transferred in full to households by the government. That is

$$M_{t+1} - M_t = T_t . \quad (29)$$

A similar equation applies to the foreign country.

### 3.3 Firms

Each firm in the world produces only one type of goods. This implies that there are  $n$  firms in the home country and  $(1 - n)$  in the foreign country. They sell their products in monopolistically competitive markets.



We assume that firms set their prices in an asynchronous fashion according to Calvo contracts. Firms sell the same item to consumers (for consumption or investment), and to firms as intermediate goods. Firms can not segment these three markets, with the result that they sell the same item at the same price in all markets.

Firms combine labour with material factors according to the following production function

$$Y_i = L^{\alpha_L} K^{\alpha_K} Z^{\alpha_Z} - Q, \quad (30)$$

where  $\alpha_L, \alpha_K, \alpha_Z > 0$  and  $\alpha_L + \alpha_K + \alpha_Z = 1$ ,  $Q$  is a fixed production cost.<sup>18</sup>  $Z$  is a CES aggregate of intermediate goods similar to equations (13), but with the same elasticities assumed for the investment goods.<sup>19</sup> The price indexes for this aggregate are therefore the same as those holding for investment goods. That is  $P_Z = P_I$ .

### 3.3.1 Composite demand and variable elasticity

In this model we assume that each firm faces a demand composed of three sub-demands: the demand for consumer goods, the demand for investment goods and the demand for intermediate goods. That is

$$D_i = \left(\frac{p_i}{P_h}\right)^{-\omega} \left(\frac{P_h}{P}\right)^{-\theta} C^W + \left(\frac{p_i}{P_{h,Z}}\right)^{-\hat{\omega}} \left(\frac{P_{h,Z}}{P_Z}\right)^{-\eta} (X^W + Z^W). \quad (31)$$

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<sup>18</sup>A fixed cost is typically introduced in models of monopolistic competition to eliminate “pure profits”. By controlling the size of  $Q$  we can control the degree of increasing returns in our model. We show that this source of increasing returns produces quantitative effects but has no qualitative implications.

<sup>19</sup>In the simulations we also considered an alternative grouping of goods, i.e. consumption goods and investment goods with the same elasticity. The main conclusion remains unaffected.

The elasticity of this demand with respect to  $p_i$  is

$$\varepsilon \equiv \left| \frac{d \log D}{d \log p_i} \right| = \omega \frac{\left(\frac{p_i}{P}\right)^{-\omega} \left(\frac{P_h}{P}\right)^{\omega-\theta} C^W}{D} + \hat{\omega} \frac{\left(\frac{p_i}{P_Z}\right)^{-\hat{\omega}} \left(\frac{P_{h,Z}}{P_Z}\right)^{\hat{\omega}-\eta} (X^W + Z^W)}{D}. \quad (32)$$

Therefore  $\varepsilon$  is an average of the intra-country elasticity of substitution for consumer goods and for the demand for “non-human factors of production” (NHF, hereafter). Clearly if  $\omega = \hat{\omega}$  then  $\varepsilon = \omega$  so that  $\varepsilon$  is constant.

The variability of the mark-up is a “natural” feature of the composite demand structure. A countercyclical markup is widely acknowledged to be an important source of real rigidity and hence it may well contribute to explaining the persistence of the real effects of monetary shock (see Rotemberg and Woodford, 1999). In terms of what we claimed in the opening sections, it should also contribute to the determination of the current account, as is shown below.<sup>20</sup>

### 3.4 Calvo contracts

We assume here that there is an exogenously given probability, say  $\gamma$ , that a firm will not adjust its price in period  $t$ . The firm’s problem can therefore be expressed as

$$\max_{p_i} \sum_{s=t}^{\infty} \gamma^{s-t} \frac{R_{s,t}}{P_s} \Pi_s,$$

where  $R_{s,t} = (1 + r_t)^{-1} (1 + r_{t+1})^{-1} \dots (1 + r_{t+s})^{-1}$  and where  $(1 + r_{t+1}) P_{t+1} = (1 + \tau_{t+1}) P_t$ . That is to say, when the firm chooses its price, it has to take

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<sup>20</sup>In this model, as in Galí (1996) and Lombardo (1999), there are multiple steady states if the symmetric equilibrium equation for the elasticity admits more than one solutions. The symmetric equilibrium equation for the elasticity is  $\varepsilon = \omega (1 - \varphi(\mu)) + \hat{\omega} \varphi(\mu)$ , where  $\mu = \varepsilon(\varepsilon - 1)^{-1}$  is the steady state markup and  $\varphi(\mu) = (X + Z)(Y)^{-1}$  is the share of NHF in total production. We don’t pursue this possibility here and refer the interested reader to the above mentioned relevant papers.

account of the probability that it will exist in the following period, in the period after that, and so on. By solving this problem and after some algebra, we obtain

$$p_t = \frac{\sum_{s=t}^{\infty} \gamma^{s-t} \frac{R_{s,t}}{P_s} \mu_s (1 - \varepsilon_s) MC_s D_s}{\sum_{s=t}^{\infty} \gamma^{s-t} \frac{R_{s,t}}{P_s} D_s (1 - \varepsilon_s)} . \quad (33)$$

The aggregate price of home produced goods is

$$P_{h,t} = (1 - \gamma) \sum_{s=0}^{\infty} \gamma^s p_{t-s} . \quad (34)$$

That is, in each period  $\gamma$  firms leave their price unchanged, while  $(1 - \gamma)$  firms set a new price. This price still holds in period  $t$  for these firms with probability  $\gamma^n$ . The aggregate price is the weighted average of all prices which were set in the past and still prevail.

In Calvo contracts the price indexes can be rewritten as

$$P_C = \left[ n P_{h,C}^{1-\theta} + (1 - n) (E P_{f,C})^{1-\theta} \right]^{\frac{1}{1-\theta}}$$

and

$$P_Z = \left[ n P_{h,Z}^{1-\eta} + (1 - n) (E P_{f,Z})^{1-\eta} \right]^{\frac{1}{1-\eta}} ,$$

where  $P_h$  is the home price index of domestically produced goods and  $P_f$  is the foreign counterpart defined in equations (15) and (16).

With the Calvo pricing assumption the current account can be written as

$$\begin{aligned}
\Delta B_{t+1} = & i_t B_t - P_t C_t - P_{I,t} X_t \tag{35} \\
& + \underbrace{P_{h,t} \left( \frac{P_{h,t}}{P_t} \right)^{-\theta} C_t^W + P_{I,t} \left( \frac{P_{h,I,t}}{P_{I,t}} \right)^{-\eta} X_t^W}_{\text{domestic value added}} \\
& + \underbrace{(1-n) P_{h,Z,t} \left( \frac{P_{h,Z,t}}{P_{Z,t}} \right)^{-\eta} Z_t^* - (1-n) E P_{f,Z,t} \left( \frac{P_{f,Z,t}}{P_{Z,t}^*} \right)^{-\eta} Z_t}_{\text{intermediate goods net export}}.
\end{aligned}$$

That is to say, home consumption and asset accumulation has to be financed by the total home *value added* plus the financial wealth, once the net imports of intermediate goods have been paid for.

Note that in equation (35) the elasticity of substitution between imported goods and domestically produced goods appears explicitly, unlike the elasticity on which the mark-up is based. We now go on to show that both types of elasticities affect the response of the current account through different mechanisms.

## 4 Linearisation and solution

The model is linearised around the symmetric equilibrium with zero bond holdings. The model is then simulated numerically under the assumption of a 1% unforeseen increase of the home money supply.

### 4.1 Equilibrium

An equilibrium for this economy is given by the set of values for each of the linearised variables, in such a way that the first order conditions for the household problem and for the firm problem are satisfied, markets clear and the economy remains bounded as  $t \rightarrow \infty$ .

The model is solved by numerical simulation and the results are shown in the following section.

## 4.2 The current account response

The response of the current account to monetary shocks depends on three broad factors: the elasticity of demand with respect to the terms of trade (the “Marshall-Lerner effect”); the response of the terms of trade to the shock (the “price effect”); and the response of the total components of demand (the “volume” effect or the “absorption” effect). Trade in intermediate goods adds both to the price effect (positively, through an increased real rigidity) and to the volume effect (negatively, through an extra source of absorption).

Investment in capital also affects the current account in this way. Nevertheless, its contribution is *negative* for both the price effect and the volume effect. The stronger the response of investment, the stronger the pressure on scarce resources and hence on costs, without the advantage of transmitting the price inertia vertically.

In all our simulations we impose values on the parameters that can be derived from the related literature,<sup>21</sup> setting  $\sigma = 2$ ,  $\zeta = 1$ ,  $\phi = 9$ ,  $\delta = 0.04$  and  $d = 0.06$ . As for the installation costs,  $\kappa$ , we follow the existing literature by setting in such a way as to dampen “sufficiently” the volatility of investments. In particular, we set  $\kappa = 5$ . The effect of reducing this value would be to increase the impact of the shock on investment. As discussed above, this would have the effect of increasing dramatically the cost of production and hence the price level. Minor adjustment costs would make a deterioration of the

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<sup>21</sup>In particular, we follow Sutherland (1998), Chari *et al.* (2000), Bergin and Feenstra (2000) and Erceg (1997). Changing the parameter values around the assigned numbers does not alter the quality of our results.

current account more likely. Overhead costs are calibrated so to have zero pure profits in equilibrium, as is common in this class of models. Overhead costs magnify the response of the current account without having any qualitative effect on the dynamics. The share of labour in production is assumed to be 0.2 with input-output and 0.7 without; the share of capital is assumed to be 0.16 with input-output, unless specified otherwise. Notice finally that imposing a constant mark-up will amount to imposing  $\varepsilon = \omega = \hat{\omega}$ . Various values are assigned to the remaining parameters as stated below.

#### 4.2.1 The current account with and without capital

Figure (1) to (9) show a set of simulations in which the steady-state level of the mark-up varies. The graphs report the dynamic response of a selection of variables to an unexpected 1% increase in the domestic money stock.

Figures (1) and (2) show a current account improvement. This is obtained by setting the elasticity of substitution between imported goods and domestically produced goods (ML hereafter) at 5 and the elasticity of the interest rate premium at  $10^{-3}$  (so that the premium just eliminates the unit root).<sup>22</sup> In the first graph the mark-up is set at 1.25 while in the second a value of 2 has been imposed.<sup>23</sup> At these levels of competition there is sufficient real rigidity

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<sup>22</sup>An ML elasticity of this magnitude has recently been suggested by Obstfeld and Rogoff (2000). Lower values have been suggested by other authors (e.g. Backus *et al.* (1994)).

<sup>23</sup>There has been much debate about the average size of the mark-up as well as its cyclicity. Small (1997), who argues against the countercyclicity of the mark-up, reports some estimated values of the latter for the United Kingdom; these are never greater than 2. Indeed, the median firm has a mark-up of about 1.1, i.e. about  $\varepsilon = 10$ . Galeotti and Schiantarelli (1998), who argue in favor of a countercyclical mark-up for the United States, provide sectoral mark-ups generally smaller than 2. Kiley (1997) obtains his countercyclical markup assuming very high steady state mark-up ( $\mu = 1.4$ ). A mark-up greater than one is not necessarily associated with pure profits: overheads might indeed absorb all the wedge

in prices to induce a large “expenditure switching” in favour of the devaluing (home) country. This effect is clearly more marked the higher the mark-up.

Figure (3) shows that reducing the monopolistic distortion, i.e. the mark-up, to 1.053 (i.e. 20/19) induces a stronger response by domestic prices and hence a deterioration of the current account. This result clearly shows that the degree of competition can have significant effects on the current account response to nominal shocks. The possibility of highlighting this fact rests on the detailed structure of modern open economy models. Earlier models in this class (e.g. Obstfeld and Rogoff (1995)) paid attention to the distinction between the ML elasticity and the degree of competition. The further contribution of this study is to show that the two elasticities (ML and that underlying the mark-up) can have significant effects, through different channels, on the current account response.

The traditional Marshall-Lerner mechanism is still clearly in operation. Figure (4) and (5) show how the mark-up effect interacts with the Marshall-Lerner effect. Here the ML elasticity is reduced to 2 (other parameters unchanged). With such low substitutability between domestic and imported goods the “expenditure switching” is reduced. The devaluing (home) country cannot benefit greatly from the devaluation; the current account is more likely to deteriorate. However with a high degree of monopolistic distortion the mark-up effect produces an improvement in the current account position.<sup>24</sup>

Figures (6)-(9) show the important role of the “input-output” structure in the 

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between price and marginal cost as in the simulation results shown in this study.

<sup>24</sup>The sign switching is clearly very impressive, especially considering the plausible set of values given to the parameters. However, it is more appropriate to think of the mark-up effect as a positive relationship between the mark-up and the current account response. In practice we can only expect, *ceteris paribus*, a milder deterioration of the current account or a more pronounced improvement in a country with less perfect competition.

dynamic response of the economy. The first two graphs report the dynamic path of an economy without the “input-output” structure, with the ML elasticity set at 2 and the elasticity of the premium still at  $10^{-3}$ . The second two graphs show an economy with “input-output” but without capital accumulation. By comparing the two settings one can easily see that the “input-output” technology adds a considerable dynamics to the economy while capital accumulation per se forces the economy to revert quickly to the steady-state, which is consistent with our earlier analysis.

#### 4.2.2 Persistence, variable mark-ups and input-output

This study shows the existence of a relationship between the degree of competition and the response of the current account to monetary shocks, and this works through the degree of real rigidity. Any factor that reduces the response of the optimal price to the monetary shock is bound to produce the same effect. Our model has another source of real rigidity built in: the potential countercyclicality of the mark-up. As Galí (1994, 1996) shows, whenever the more procyclical demand component has a lower elasticity of substitution, the mark-up will move counter-cyclically.<sup>25</sup>

In our model we find that the countercyclicality of the mark-up is positively related to the size of the steady-state mark-up. Indeed, we also find that the countercyclicality is not negligible only for extremely high mark-ups. This implies that this source of real rigidity depends heavily on the real rigidity produced by the degree of competition: the former is high when the latter is high.

The following table shows some simulation results in relation to the coun-

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<sup>25</sup>This property is highlighted by Rotemberg and Woodford (1999) and is used in Kiley (1997) to generate persistence in a closed economy model.



tercyclicalities of the mark-up and the current account. It also shows the effect on the persistence of the “output gap”, i.e. the deviation of the home output from its long-run level, as defined by the percentage coverage of the output gap by the second period. We select two periods for the sake of convenience. In the second period about 75% of prices have been adjusted. The smaller the output gap adjustment compared with the exogenous price adjustment, the bigger the endogenous persistence produced by the model.<sup>26</sup>

Case	$\varepsilon = 2$			
	$\tilde{M} = 1\%$	$\Delta Y_{gap}$	$\Delta \mu$	$\Delta B$
(1) $K \ \& \ Z; \hat{\omega} - \omega = 1$	61%	-0.30%	4.7%	
(2) $K \ \& \ Z; \hat{\omega} - \omega = 0$	67%	0	3.45%	
(3) $Z \ \text{only}; \hat{\omega} - \omega = 1$	46%	-0.34%	10.22%	
(4) $Z \ \text{only}; \hat{\omega} - \omega = 0$	63%	0	6.73%	

Table 1: Persistence and mark-up variability.

Cases (1) and (2) in table (1) relate to an economy with both “input-output” and capital accumulation. Cases (3) and (4) in the same table refer to an economy without capital accumulation. The table shows that a countercyclical mark-up increases persistence and improves the response of the current account to monetary shocks.<sup>27</sup>

<sup>26</sup>For this experiment we have set  $\eta = 20$  and  $\theta = 1.5$  so to emphasise the mark-up variability. This experiment does not aim at realism. As we claim in the text, this source of “real rigidity” does not seem to be of importance in plausible parameter ranges. The elasticity of the premium is set to  $10^{-3}$ .

<sup>27</sup>We also experimented with a more volatile demand for investment ( $\kappa = 0.1$ ). The result was a more marked countercyclicalities of the mark-up at the expenses of persistence. This is because the increase in costs of production due to the large shift in demand for investment goods more than offsets the reduction in mark-up. Nevertheless, the underlying result did hold in terms of real rigidity and the current account.

The economy without capital accumulation shows more persistence. The increase in persistence due to the variable markup is also more marked in the economy without capital accumulation. These results are considerable only at very high degree of monopolistic distortion. Therefore, while they confirm that important sources or real rigidity would have consequences on the response of the current account, the markup variability induced by the composite demand model contributes only very marginally to the dynamics of our model.

Finally, table (2) shows how the “input-output” technology affects both persistence and the response of the current account. In this experiment there is no capital accumulation and we ML elasticity was set at  $-5$  and the mark-up at 2.

material share	$\Delta Y_{gap}$	$\Delta B$
$\alpha_Z = 0.8$	51%	1.82%
$\alpha_Z = 0.2$	66%	0.60%

Table 2: Persistence and input-output.

As expected, a higher share of intermediate goods in production increases persistence and tends to improve the current account response to the 1% increase in the home money stock.

## 5 Conclusions

This study has shown that the degree of monopolistic competition, as measured by the mark-up, is negatively related to the elasticity of the optimal price with respect to nominal shocks. This positive relationship between the mark-up and the degree of real rigidity is an important source of persistence of the real effects of monetary shocks as well as an important determinant

of the response of the current account to the same shocks. The mechanism through which this relationship operates in this model is simple: the higher the mark-up the lower the share of total output attributable to the factors of production. If intermediate goods are sold at the same price as final goods (or a constant proportion), a lower quantity of intermediate goods are produced per unit of output. This implies reduced pressure on the scarce resources and hence reduced production costs. The optimal price set by the firms, and the aggregate price level, change proportionally less, the higher the mark-up. In an open economy this translates into an increased “expenditure switching” consequent upon a monetary shock. While the exchange rate depreciation, per se, makes domestic goods more attractive, the increased real rigidity reduces their price response and hence allows for a stronger demand switching. The current account clearly benefits from this.

The New Open Economy literature has recently emphasised the need to distinguish between the elasticity of substitution between domestic and imported goods and the degree of competition in the domestic economy. The former elasticity is at the centre of the Marshall-Lerner condition, and hence that which has traditionally been associated with the current account response to a devaluation. Our paper shows that the degree of competition can also affect the response of the current account, and through a distinct mechanism.

The composite demand structure used in our set-up also allows for a countercyclical mark-up. This further lessens the response of the optimal price to the monetary shock, again to the benefit of the current account.

While we have assumed imperfections in the goods market, the main conclusions of this paper would, in fact, carry over to a model with labour market imperfections. In that case the degree of unionisation in the labour market could be the counterpart to our measure of goods market competition.

This paper contributes both to the vast literature that addresses the persistence issue and to the New Open Economy literature on the current account dynamics. It does so by highlighting the close connection between the sources of “real rigidity” - and hence persistence - and the response of the current account to nominal shocks.

The empirical relevance of the specific mechanism developed in our model remains an open question which deserves further scrutiny.

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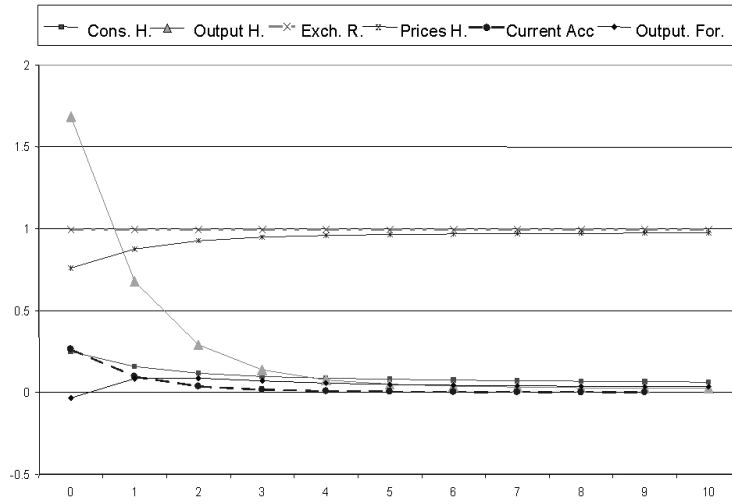


Figure 1: Current account improvement:  $\varepsilon = 5$ ,  $\theta = \eta = 5$ .

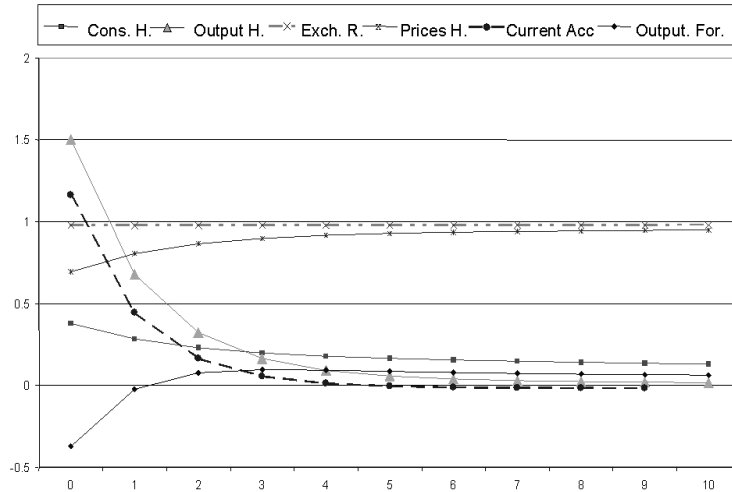


Figure 2: Current account improvement:  $\varepsilon = 2$ ,  $\theta = \eta = 5$ .

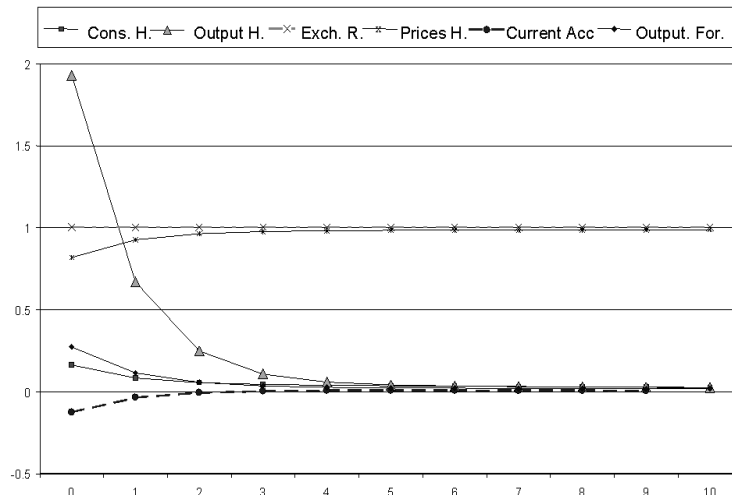


Figure 3: Current account deterioration:  $\varepsilon = 20$ ;  $\theta = \eta = 5$ .

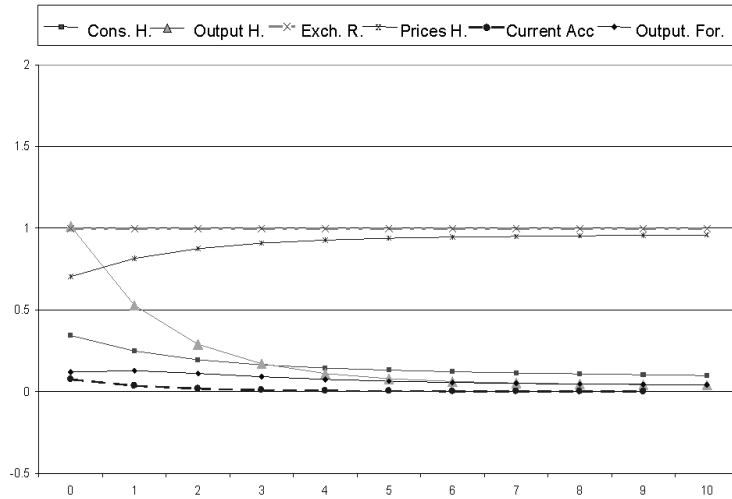


Figure 4: Current account improvement:  $\epsilon = 2, \theta = \eta = 2$ .

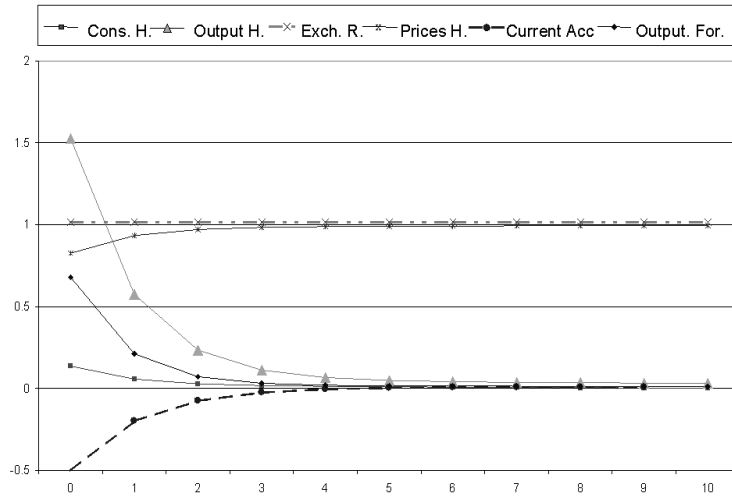


Figure 5: Current account deterioration:  $\epsilon = 20, \theta = \eta = 2$ .

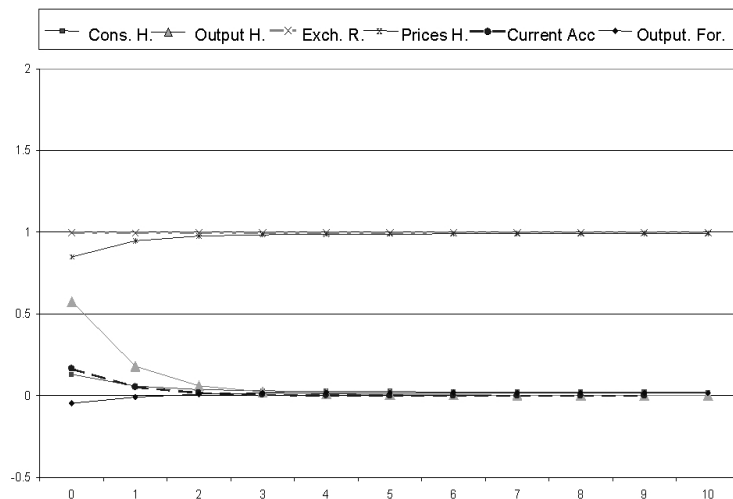


Figure 6: No input-output:  $\varepsilon = 2, \theta = \eta = 2$ .

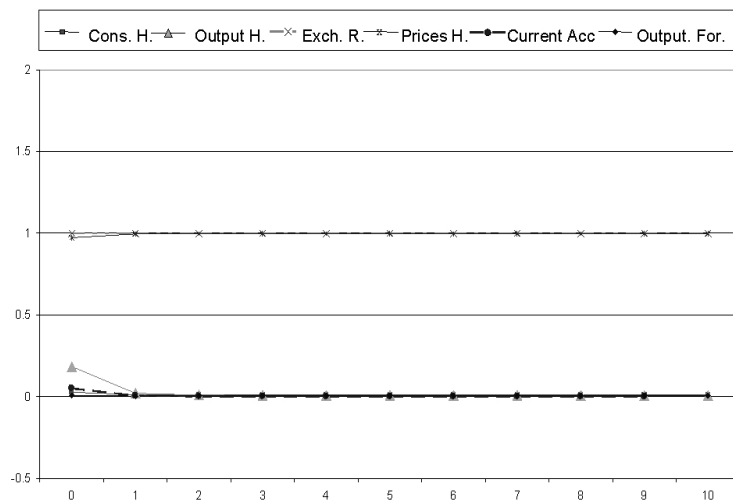


Figure 7: No input-output:  $\varepsilon = 20, \theta = \eta = 2$ .

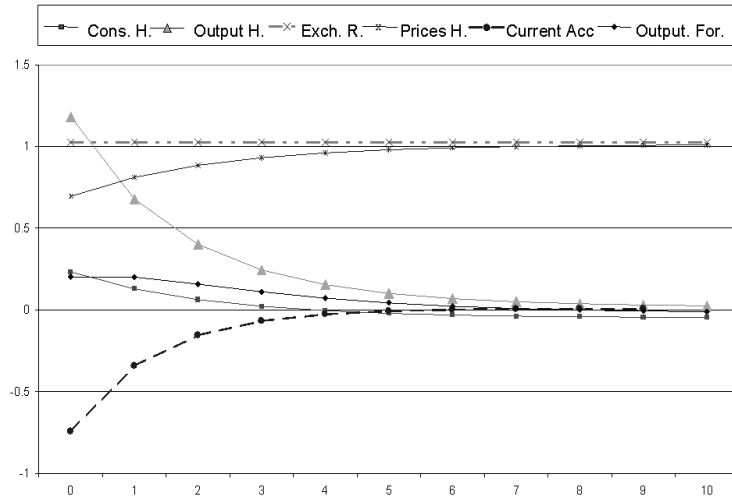


Figure 8: No capital:  $\varepsilon = 20$ ,  $\theta = \eta = 2$ .

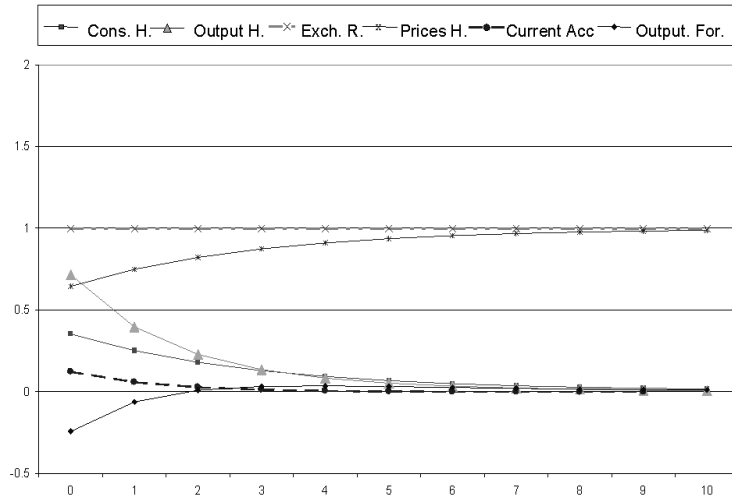


Figure 9: No capital:  $\varepsilon = 2$ ,  $\theta = \eta = 2$ .

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