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THE CONSUMPTION-REAL EXCHANGE RATE ANOMALY: NON-TRADED GOODS, INCOMPLETE MARKETS AND DISTRIBUTION SERVICES

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Resumen

El tipo de cambio real es volátil y tiende a moverse en dirección opuesta respecto a los consumos relativos entre economías. Chari, Kehoe y MCGrattan (2002) se refieren a la incapacidad de los modelos de replicar este hecho estilizado como la anomalía *consumo-tipo de cambio real*. En este trabajo presentamos un modelo internacional del ciclo de negocios real similar al propuesto por CKM pero extendido considerando bienes no transables y una estructura de mercados de activos incompleta que permite resolver la anomalía. Bienes no transables amplifican los efectos riqueza que emergen de la estructura de activos incompleta generando un comovimiento negativo entre tipo de cambio real y consumos relativos. El modelo lo hace relativamente bien con otros momentos del ciclo de negocios internacional y, una vez que se introducen cosots de distribución en términos de bienes no transables, genera un tipo de cambio real tan volátil como el observado en los datos. Los resultados resultan robustos a la introducción de rigideces nominales y –en contraste con CKM- no existe la necesidad de choques monetarios para explicar la dinámica del tipo de cambio real.

Abstract

The real exchange rate is volatile and tends to move in opposite direction with respect to relative consumption across countries. Chari, Kehoe and McGrattan (CKM, 2002) refer to the inability of models to replicate the last stylized fact as the consumption-real exchange rate anomaly. In this paper we show that an international RBC model similar to the one proposed by CKM but extended by considering nontraded goods and an incomplete asset market structure can solve this anomaly. Non tradable goods amplify wealth effects that arise from the incomplete assets market structure generating a negative comovement between the real exchange rate and relative consumption. The model performs reasonable well with other business cycle moments and, by adding distribution services in terms of nontraded goods, it generates a real exchange rate as volatile as in the data. Results are robust to the addition of nominal price rigidities and -in contrast with CKM- there is no need of monetary shocks to account for the real exchange rate dynamics.

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1 Introduction

Chari, Kehoe and McGrattan (2002, hereafter CKM) attempts to explain the volatility and persistence of the real exchange rate by building a model with sticky prices and local currency pricing. Their main finding is that monetary shocks and complete markets, along with a high degree of risk aversion and price stickiness are enough to account for real exchange rate volatility, and to a less extent for its persistence. However, their model find it difficult to account for the observed negative correlation between real exchange rates and relative consumption across countries, a fact that they labeled *the consumption-real exchange rate anomaly*. In addition, CKM show that the most widely used form of asset market incompleteness does not eliminate the anomaly[1]. They argue that their results stems from the fact that wealth effects arising from market incompleteness are too small.

In this paper, we address the *consumption real exchange anomaly* by generating meaningful wealth effects in a dynamic stochastic general equilibrium model with imperfect competitors. In achieving our goal we build our economy along the lines of CKM and Stockman and Tesar (1995), modified to allow for some features that we expect will help the model produce fluctuations like those in the data. First, we consider an incomplete asset market structure as in CKM but unlike them the net foreign assets position (*NFA*) is stationary. Second, we introduce non-traded goods as in Stockman and Tesar (1995) in order to generate meaningful wealth effects. The key difference in our analysis relative to CKM is that the introduction of nontraded goods. We argue that it is the absence of nontraded goods in CKM´s paper what inhibits wealth effects and what makes their model to deliver almost perfect risk sharing even with incomplete markets. Finally, following Burstein, Neves and Rebelo (2003), we add distribution services in terms of nontraded goods which endogenously generates deviations from the law of one price both at consumer and producer level[2]. Distribution services will contribute to endogenously generate real exchange rate volatility.

In our model, fluctuations in the real exchange rate are generated by the presence of non-traded goods in addition to the standard home bias channel. Non traded goods are appealing in an incomplete market setup because they permit us to capture and to asses wealth effects that arise from the associated traditional transfer problem[3]. Lane and Milesi-Ferretti (2001) argue that a model with only tradable goods may neglect the potential impact on transfers from the relative price of non-traded goods. Hence, the wealth effect stemming from the level of net foreign assets on the labor supply may be better captured in a heterogenous sector model. In addition, Betts and Kehoe (2005) and Burstein, Eichenbaum and Rebelo (2005a) have highlighted the role of nontraded goods in explaining the real exchange rate volatility. They

[1] Backus and Smith (1993) reported the same puzzle in an IRBC model with non-traded goods. Obstfeld and Rogoff (2000) list this "disconnect" among the central unresolved puzzles in international macroeconomics.

[2] Corsetti and Dedola (2005) have also considered the role of market segmentation in the tradable sector generated by the presence of nontradable goods in a two period monetary model.

[3] Under the transfer effect, a positive home trade balance implies that Home´s production exceeds its consumption in value, so that Home is making a transfer of resources to the Foreign. Home´s relative wage decreases and the range of goods homes produces for exports increases. Accompanying this change is a fall in Home´s real wage, a fall in its real exchange rate, and a fall in its terms of trade. In this contexto, debtor (creditor) countries tend to have more depreciated (appreciated) real exchange rates. See Lane and Milesi-Ferretti (2004) for recent evidence on the transfer problem.

find that at least one third of the real exchange variance is explained by fluctuations in the relative price of nontraded goods to traded goods.

Our quantitatively framework yields the following main results. First, the benchmark model with incomplete asset markets and nontradable goods is able to explain the *consumption real exchange rate anomaly*. The predicted correlation between the real exchange rate and relative consumptions is consistently negative. Importantly, our results are obtained with a realistic value of the elasticity of substitution between tradable goods[4]. Thus, we find adding nontraded goods to an incomplete markets model does importantly alter the predictions of a model with tradable goods only (as in CKM). In our model, a productivity shock in the traded sector delivers an appreciation of both the terms of trade and the real exchange rate vis-a-vis an increase in relative consumptions. Following the shock, domestic consumption increases and foreign consumption decreases, so relative consumptions increase. Wealth effects generate a decrease in investment and consequently output decrease but in a less magnitude than the decrease in consumption plus investment, therefore it follows that the country accumulates net foreign assets. Unlike CKM, a large NFA accumulation is achieved by the presence of nontraded goods. Thus, a meaningful wealth effect induces a decrease in the labor supply and, therefore, an increase in real wages is observed, causing an increase in domestic prices which triggers both a terms of trade and a real exchange rate appreciations[5].

Second, the benchmark economy is able to generate large volatility in international prices by relying only on sector specific productivity shocks, in contrast to CKM who rely on monetary shocks. Thus our results puts into debate the role of nominal rigidities and monetary shocks in explaining the real exchange rate dynamics and, instead, gives support to the evidence presented by Betts and Kehoe (2005) and Burstein et al. (2005a), regarding the importance of nontraded goods[6]. Furthermore, by adding distribution services to the benchmark economy, we generate even larger volatilities in international prices compared to the ones observed in the data and, simultaneously, a negative correlation between the real exchange rate and relative consumption is obtained. In short, distribution services by lowering the price elasticity of import demand, enhances volatility in the real exchange rate and helps to account for the *anomaly.*

Third, our sensitivity analysis show that the model with incomplete markets and tradable goods only predicts a close to one correlation between the real exchange rate and relative consumptions, therefore, movements in the terms of trade are sufficient to yield perfect risk-sharing. Hence, the lack of nontradability mitigates wealth effects in an important way. We also show that a benchmark model with nominal rigidities in the nontraded sector and an endogenous taylor rule contributes in explaining both the *anomaly* and in adds volatility to the real exchange rate fluctuations. Moreover, we find that the smaller the elasticity of

[4] In a model with tradable goods and financial autarky, low values of the price elasticity of tradable goods will allow obtain a negative correlation between the real exchange rate and relative cosumptions vis a vis a volatile real exchange rate.

[5] Corsetti, Dedola and Leduc (2004) provide empirical evidence suporting the idea that a productivity shock generates simultaneously terms of trade and real exchange rate appreciations.

[6] In a recent paper, Rabanal and Tuesta (2005) perform bayesian structural estimation to a monetary model similar to the one proposed by CKM. They show that monetary shocks have played a minor role in explaining the behavior of the real exchange rate, while both demand and technology shocks have been important.

substitution between tradable goods across countries, the larger the volatility of the real exchange rate and, in addition, the negative correlation between the real exchange rate and relative consumptions becomes smaller.

Recently, other authors have proposed similar avenues to ours to addressed the *consumption-real exchange rate anomaly*. Corsetti, Dedola and Leduc (2004) show that a low price elasticity of demand for import goods, generated by the presence of distribution services, can hinder risk-sharing and it might contribute to explain the *anomaly*. Yet, their results rely on tow low values of the exogenous elasticity of substitution between tradable goods[7]. Moreover, different from the previous authors we develop a model with *imperfect competition* in production similar to CKM, so we generate deviations from the law of one price both at the border and at the consumer level. On the other hand, Benigno and Thoenissen (2004) introduce non-tradable goods in a model with incomplete markets where prices are perfectly flexible and markets are competitive. Similar to our findings, they attribute a key role for the nontradable goods, through the Balassa-Samuelson effect, to be crucial at explaining the *anomaly*[8].

Finally, recent contributions have also included distribution services to explain the real exchange rate dynamics and, in particular, to account for the differences between import prices and consumer prices (Burstein, Eichenbaum and Rebelo, 2005b). We take a step further by modelling distribution services in an set up with monopolistic competitors in a dynamic general equilibrium model. Distribution services coupled with monopolistic competitors permits the model to generate deviations from the law of one price both at wholesale and at retail price levels. Corsetti and Dedola (2005) introduce the same mechanism in a model with nominal rigidities, although in their framework they do not evaluate the merits of distributive services in a dynamic setting.

The paper is structured as follows. In Section 2 we introduce the benchmark model and the extensions. In Section 3 we analyze the quantitative properties of the model, we also illustrate the key mechanism behind our findings and we then perform a sensitivity analysis. Finally, section 4 concludes.

2 The Model

The model is a modification of CKM (2002) allowing for the presence of non-tradable goods in the line of Stockman and Tesar (1995). We also generate deviations from the law of one price at the border due to the introduction of distribution services in the line of Burstein, Neves and Rebelo (2003). Thus, firms producing tradable and nontradable goods are monopolistic competitors[9]. In addition, in our benchmark economy, we introduce an incomplete asset market structure with stationary net foreign asset positions.

[7] Trade studies typically find values for the elasticity of import demand to respect to price (relative to the overall domestic consumption basket) in the neighborhood of 5 to 6, see Trefter and Lai (1999). Most of the NOEM models consider values of 1 for this elasticity which arises from the assumption of Cobb-Douglas preferences in aggregate consumption.

[8] Similarly, Ghironi and Melitz (2005) findings suggest that the Balassa-Samuelson dominates the home bias effect triggering appreciations in the real exchange rate vis as vis an increase in relative consumptions. Their mechanism relies on aggregate productivity shocks rather than sector specific shocks.

[9] Coresetti, Dedola and Leduc (2004) introduce distribution services in an standard international RBC model with perfectly competitive setting. Here instead, we allow for monopolistic competition. This assumption generates deviations from the law of one price at the border.

2.1 Preferences

We assume that there are two countries, home (H) and foreign (F), of equal size[10]. Brands of traded goods are indexed by $h \in [0,1]$ in the domestic country and by $f \in [0,1]$ in the foreign country. Similarly, households and workers are indexed by h and f in the domestic and foreign country, respectively. Brands of nontradable goods are indexed by $n \in [0,1]$.

The preferences of a household in country H are assumed to be separable in their arguments[11]:

$$U_t = E_0 \left[\sum_{t=0}^{\infty} \beta^t \left(U(C_{t+s}, L_{t+s}) \right) \right], \tag{1}$$

where E_0 denotes the expectation conditional on the information set at date $t = 0$, and β is the intertemporal discount factor, with $0 < \beta < 1$. C_t denotes the level of consumption in period t, L_t denotes labor supply. We define the consumption index as

$$C_t \equiv \left[\gamma^{1/\varepsilon} \left(C_t^T \right)^{\frac{\varepsilon-1}{\varepsilon}} + (1-\gamma)^{1/\varepsilon} \left(C_t^N \right)^{\frac{\varepsilon-1}{\varepsilon}} \right]^{\frac{\varepsilon}{\varepsilon-1}}, \tag{2}$$

where ε is elasticity of substitution between tradable (C_t^T) and non-tradable (C_t^N) goods, and γ is the share of tradable goods in the consumption basket at home. The sub-index of consumption for traded goods is defined as:

$$C_t^T \equiv \left[\lambda^{\frac{1}{\theta}} \left(C_t^H \right)^{\frac{\theta-1}{\theta}} + (1-\lambda)^{\frac{1}{\theta}} \left(C_t^F \right)^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}}, \tag{3}$$

where θ is elasticity of substitution between home and foreign tradable goods, λ represents the degree of home bias in preferences. C_t^H and C_t^F are indexes of consumption across the continuum of differentiated goods produced in country H and F, and are given by:

$$C_t^H \equiv \left[\int_0^1 c_t(h)^{\frac{\sigma-1}{\sigma}} dh \right]^{\frac{\sigma}{\sigma-1}}, C_t^F \equiv \left[\int_0^1 c_t(f)^{\frac{\sigma-1}{\sigma}} df \right]^{\frac{\sigma}{\sigma-1}}, \tag{4}$$

where $\sigma > 1$ is the elasticity of substitution across goods produced within country H, denoted by $c_t(h)$, and country F, denoted by $c_t(f)$. Similarly, the consumption of non-traded goods in the home country is given by

$$C_t^N \equiv \left[\int_0^1 c_t^N(n)^{\frac{\sigma-1}{\sigma}} dn \right]^{\frac{\sigma}{\sigma-1}}, \tag{5}$$

where $c_t^N(n)$ denotes the consumption of each individual non-traded good.

[10] The population in each country is normalized at unity. It is straightforward to allow for different population in each country as in Clarida, Gali and Gertler (2002) and Benigno and Benigno (2003).

[11] The convention will be to use an asterisk to denote the counterpart in the foreign country of a variable in the home country (i.e. if aggregate consumption is C in the home country, it will be C^* in the foreign country and so on. The same applies to the model's parameters.

Individual demands for home and foreign tradable, and nontradable goods are given by:

$$\begin{aligned}
c_t(h) &= \lambda\gamma\left(\frac{p_t(h)}{P_t^H}\right)^{-\sigma}\left(\frac{P_t^H}{P_t^T}\right)^{-\theta}\left(\frac{P_t^T}{P_t}\right)^{-\varepsilon}C_t, \\
c_t(f) &= (1-\lambda)\gamma\left(\frac{p_t(f)}{P_t^F}\right)^{-\sigma}\left(\frac{P_t^F}{P_t^T}\right)^{-\theta}\left(\frac{P_t^T}{P_t}\right)^{-\varepsilon}C_t, \text{ and} \\
c_t^N(n) &= (1-\gamma)\left(\frac{p_t^N(n)}{P_t^N}\right)^{-\sigma}\left(\frac{P_t^N}{P_t}\right)^{-\varepsilon}C_t.
\end{aligned}$$

In this context, the consumer price index that corresponds to the previous specification is given by

$$P_t \equiv \left[\gamma\left(P_t^T\right)^{1-\varepsilon} + (1-\gamma)\left(P_t^N\right)^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}}, \tag{6}$$

where the price index for tradable goods has the following form

$$P_t^T \equiv \left[\lambda\left(P_t^H\right)^{1-\theta} + (1-\lambda)\left(P_t^F\right)^{1-\theta}\right]^{\frac{1}{1-\theta}}, \tag{7}$$

with prices of home and foreign tradable goods, and non-tradable goods defined, respectively as

$$P_t^H \equiv \left[\int_0^1 p_t(h)^{1-\sigma}dh\right]^{\frac{1}{1-\sigma}}, \; P_t^F \equiv \left[\int_0^1 p_t(f)^{1-\sigma}df\right]^{\frac{1}{1-\sigma}},$$

$$P_t^N \equiv \left[\int_0^1 p_t^N(n)^{1-\sigma}dn\right]^{\frac{1}{1-\sigma}},$$

where $p_t(i)$ for $i = h, f$, and $p_t^N(n)$ are prices sold in the home country, in home currency and at consumer level, for both tradable and nontradable goods, respectively. Prices P_t^*, $P_t^{H^*}$, $P_t^{F^*}$ and $P_t^{N^*}$ are analogously defined, where $(1-\lambda^*)$ would be the fraction of foreign-produced goods in the foreign consumption aggregate (i.e. the foreign degree of home bias). We define the real exchange rate, Q_t, as the relative price between the aggregate foreign prices and domestic prices, $Q_t = \frac{P_t^*}{P_t}$

A feature of our specification is the presence of distribution costs which imply a wedge between producer and consumer prices. This follows closely Burstein, Neves and Rebelo (2003). With *competitive firms* in the distribution sector, the consumer price of good h will be given by

$$p_t(h) = \overline{p}_t(h) + \kappa P_t^N \tag{8}$$

where $\overline{p}_t(h)$ denotes the price of home goods at the producer level and κ are the units of a basket of differentiated non-traded goods necessary to bring one unit of traded goods to the consumers

$$\kappa = \left[\int_0^1 \kappa(n)^{\frac{\sigma-1}{\sigma}}dn\right]^{\frac{\sigma}{\sigma-1}} \tag{9}$$

The Dixit-Stiglitz index that also applies to the consumption of differentiated non-traded goods[12]. For the rest of the paper, upper bar represents prices at producer level.

[12]For simplicity, we assume there are no distribution costs in the delivery of non-tradable goods.

In a model without distribution services the law of one price holds at every period. Distribution services along with the assumption of monopolistic competition permit the model to generate deviation from the law of one price both at border and at consumer level. Notice that purchasing power parity (PPP) does not hold in the model because of the presence of either home-bias in preferences or non traded goods.

2.2 Alternative Asset Market Structures

We evaluate the merits of both models with and without distribution services under two alternative asset market structures: compete and incomplete markets[13].

2.2.1 Incomplete and Imperfect Asset Markets

For modelling simplicity, we choose to model incomplete markets with two risk-free one-period real bonds denominated in domestic and foreign aggregate consumption bundle units, respectively, and a cost of bond holdings is introduced to achieve stationarity[14]. One bond is denominated in domestic consumption bundle and the other one in foreign consumption bundle. Then, the budget constraint of the domestic households in units of domestic consumption bundle is given by:

$$\frac{B_t^H}{R_t} + \frac{B_t^F \frac{P_t^*}{P_t}}{R_t^* \phi\left(B_t^F \frac{P_t^*}{P_t}\right)} \leq B_{t-1}^H + B_{t-1}^F \frac{P_t^*}{P_t} + W_t L_t - C_t - I_t + R_t^K K_{t-1} + \Pi_t \tag{10}$$

where W_t is the aggregate real wage, R_t and R_t^* are the gross real bond´s yield in domestic and foreign bonds, and Π_t are real profits for the home consumer. We assume that each consumer holds one firm in each sector and there is no trade in firms' shares. B_t^H is the home household's holding of the risk free domestic real bond. $B_t^F \frac{P_t^*}{P_t}$ is the home household's holding of the foreign risk-free real bond expressed in home consumption units. The function $\phi(.)$ depends on the real holdings of the foreign assets in the entire economy, and is taken as given by the domestic household[15]. $\phi(.)$ introduces a convex cost that allows to obtain a stationary net foreign asset position and a well-defined steady state, and captures the costs of undertaking positions in the international asset market[16]. For simplicity we assume that foreign residents can only allocate their wealth in bonds denominated in the foreign consumption bundle.

Households rent capital to the intermediate good producing firms. Capital is predetermined at the beginning of the period. We assume that investment is carried out using either traded or non-traded

[13] Baxter and Crucini (1995) highlight the role of market incompletness in internationa real business cycle models (IRBC). They show that if shocks are very persistent -without spillovers-, adding incomplete markets changes importantly the prediction of IRBC models.

[14] Benigno (2001), Schmitt-Grohe and Uribe (2001) and Kollmann (2002) develop small open-economy models introducing the same cost to achieve stationarity. Heathcote and Perri (2001) make also a similar assumption in a two-country RBC model.

[15] As Benigno (2001) points it out, some restrictions on $\phi(.)$ are necessary: $\phi(0) = 1$; assumes the value 1 only if $B_{F,t} = 0$; differentiable; and decreasing in the neighborhood of zero.

[16] Another way to describe this cost is to assume the existence of intermediaries in the foreign asset market (which are owned by the foreign households) who can borrow and lend to households of country F at a rate $(1 + r^*)$, but can borrow from and lend to households of country H at a rate $(1 + r^*)\phi(.)$.

goods[17]:

$$I_t = \left[\gamma^{1/\varepsilon} \left(I_t^T \right)^{\frac{\varepsilon-1}{\varepsilon}} + (1-\gamma)^{1/\varepsilon} \left(I_t^N \right)^{\frac{\varepsilon-1}{\varepsilon}} \right]^{\frac{\varepsilon}{\varepsilon-1}} \tag{11}$$

and can be freely allocated between traded $\left(K_T^h\right)$ and non traded sectors $\left(K_{NT}^h\right)$,

$$K_t = K_t^T + K_t^N \tag{12}$$

and the law of motion for the capital in both sectors is given by

$$K_t^i = (1-\delta) K_{t-1}^i + I_t^i + \frac{b}{2} \left(\frac{I_t^i}{K_{t-1}^i} \right)^2 \qquad for \ i = T, NT \tag{13}$$

where b is an adjustment cost in changing the capital stock employed by each intermediate goods producer and δ is the depreciation rate, as in CKM.

As Benigno (2001) we further assume that the initial level of wealth is the same across all households belonging to the same country. This assumption combined with the fact that all households within a country work for all firms sharing the profits in equal proportion, implies that within a country all the households face the same budget constraint.

The conditions characterizing the allocations of domestic and foreign consumption, and holding of real bonds are:

$$U_C(C_t) = R_t \beta E_t \left\{ U_C(C_{t+1}) \right\} \tag{14}$$

$$U_C^*(C_t^*) = R_t^* \beta E_t \left\{ U_C^*\left(C_{t+1}^*\right) \right\} \tag{15}$$

$$U_C(C_t) = R_t^* \phi \left(B_{F,t} \frac{P_t^*}{P_t} \right) \beta E_t \left\{ \frac{Q_{t+1}}{Q_t} U_C(C_{t+1}) \right\} \tag{16}$$

$$\frac{B_{F,t} \frac{P_t^*}{P_t}}{(1+r_t^*) \phi \left(B_{F,t} \frac{P_t^*}{P_t} \right)} = B_{F,t-1} \frac{P_t^*}{P_t} + \frac{P_t^H C_t^H}{P_t} + \frac{P_t^{H^*} C_t^{H^*}}{P_t} + \frac{P_t^N Y_t^N}{P_t} - C_t - I_t \tag{17}$$

Equations (14) and (15) correspond to the Euler equations of both home and foreign consumers, respectively. Equation (16) represents the holdings by a home household of the foreign bond. Finally, equation (17) relates the current account balance with the trade balance. From these conditions we are able to derive both the new uncovered interest parity and the risk-sharing equilibrium condition which are affected by the net foreign asset position of the domestic economy[18].

The first order conditions with respect to the labor supply implies

$$U_L(L_t) = U_C(C_t) W_t \tag{18}$$

[17] Price deflators for consumption and investment are the assumed to be same.

[18] The equation for the rental rate of capital is given by

$$\frac{U_C(C_t)}{\left[1 - b\left(\frac{I_t^i}{K_{t-1}^i} - \delta\right)\right]} = E_t \beta U_C(C_{t+1}) R_{t+1}^k + \frac{E_t \beta U_C(C_{t+1})}{1 - b\left(\frac{I_{t+1}^i}{K_t^i} - \delta\right)} \left[(1-\delta) - \frac{b\left(\frac{I_t^i}{K_{t-1}^i} - \delta\right)^2}{2} + b\left(\frac{I_{t+1}^i}{K_t^i} - \delta\right)\left(\frac{I_{t+1}^i}{K_t^i}\right) \right]$$

where R_{t+1}^k represents the rental rate of capital.

2.2.2 Complete markets

Since we have defined the real exchange rate as $Q_t \equiv \frac{P_t^*}{P_t}$. Under both domestic and international complete markets[19], it follows that the real exchange rate is proportional to the ratio of marginal utilities across countries (see CKM for details)[20].

$$Q_t = k_o \frac{U_C(C_t^*)}{U_C(C_t)} \tag{19}$$

where k_o is a function of predetermined variables. From (19), we can see that the relative consumption across countries is proportional to real exchange rate. This equilibrium condition predicts a positive and high cross-correlation between the real exchange rate and the relative consumptions[21].

2.3 Price Setting with Distribution Sector

As it was previously mentioned, monopolistic competition is a key assumption to obtain deviations from the law of one price at the border once distribution services are taking into account. In order to make simpler the model we assume flexible prices[22]. In this section we show how a representative firm endogenously charges different prices across countries due to the presence of distribution services. We focus on domestic firms, price setting for foreign firms can be derived analogously.

2.3.1 Non-Tradable Sector

In this model suppliers behave as monopolists in selling their products, although they confront flexible prices. Then, firms in the non-tradable sector face the following maximization problem, where profits are expressed in terms of aggregate consumption:

$$Max_{p_t^N(n)} \left[\frac{p_t^N(n) y_t^{N,d}(n)}{P_t} - MC_t^N y_t^{N,d}(n) \right] \tag{20}$$

subject to

$$y_t^{N,d}(n) = \left(\frac{p_t^N(n)}{P_t^N} \right)^{-\sigma} \left[C_t^{N,d}(n) + \kappa_t^d(n) \right], \tag{21}$$

$$\begin{aligned}
C_t^{N,d} &= (1-\gamma) \left(\frac{P_t^N}{P_t} \right)^{-\varepsilon} C_t, && (22) \\
\kappa_t^d(n) &= \kappa \left[\int_0^1 c_t(h) dh + \int_0^1 c_t(f) df \right] && (23) \\
&= \kappa\gamma \left[\lambda \left(\frac{P_{H,t}}{P_{T,t}} \right)^{-\theta} + (1-\lambda) \left(\frac{P_{F,t}}{P_{T,t}} \right)^{-\theta} \right] \left(\frac{P_{T,t}}{P_t} \right)^{-\varepsilon} C_t, && (24)
\end{aligned}$$

[19] The consumers in both economies can trade contingent one-period real bonds denominated in home consumption bundles.

[20] Baxter and Crucini (1993) used the same assumption in an IRBC model in order to explain the saving-investment correlation.

[21] Without preference shocks and with separable utility function, this condition implies a perfect correlation between the real exchange rate and relative consumptions.

[22] Selaive and Tuesta (2003a) generate low exchange rate pass-through by introducing distribution services in a model with nominal rigidities without capital.

where $y_t^{N,d}(n)$ is total individual demand for a given type of nontraded good, which is further composed by the demand of nontraded goods for consumption, $C_t^{N,d}$, and the demand for distribution services by the tradable firms ,$\kappa_t^d(n)$,. $MC_t^N \equiv \frac{W_t^{\alpha^N}\left(R_t^k\right)^{(1-\alpha^N)}}{\Phi^N Z_t^N}$ corresponds to the real marginal cost in the non-tradable sector in terms of aggregate goods.

Each firm produces according to the following production function

$$y_t^N(n) = Z_t^N \left(L_t^N\right)^{\alpha^N} \left(K_{t-1}^N\right)^{1-\alpha^N} \tag{25}$$

where Z_t^N is the country-specific productivity shock to the non-tradable sector at time t . The supplier maximizes (20) with respect to $p_t^N(n)$ given the demand function and taking as given the sequences of prices $\left\{P_t^H, P_t^F, P_t^T, P_t^N, P_t, C_t\right\}$ for $i = H, F$. The optimal choice of $p_t^N(n)$ is:

$$\frac{p_t^N(n)}{P_t} = \frac{P_t^N}{P_t} = \frac{\sigma}{(\sigma-1)} \frac{W_t^{\alpha^N}\left(R_t^k\right)^{(1-\alpha^N)}}{\Phi^N Z_t^N} \tag{26}$$

where $\Phi^N = (\alpha)^{\alpha^N}(1-\alpha^N)^{(1-\alpha^N)}$ and R_t^k is the rental rate of capital. while the optimal capital-output ratio is given by:

$$\frac{W_t L_t^N}{\alpha^N} = \frac{R_t^k K_{t-1}^N}{(1-\alpha^N)} \tag{27}$$

Since all non-traded goods producers face the same marginal cost, they set the same price[23].

2.3.2 Tradable Sector

In the benchmark model the tradable sector is completely flexible. Yet, the presence of distribution services intensive in local non-traded goods will imply different demand elasticities across markets, therefore, firms will charge different prices in each market. Then, firms face the following maximization problem:

$$Max_{\overline{p}(h),\overline{p}^*(h)}\,(1-\tau)\left\{\left[\frac{\overline{p}_t(h)}{P_t} - MC_t^T\right] y_t^d(h) + \left[\frac{P_t^*}{P_t}\frac{\overline{p}_t^*(h)}{P_t^*} - MC_t^T\right] y_t^{*,d}(h)\right\} \tag{28}$$

subject to the individual home and foreign demands

$$y_t^d(h) = c_t^d(h) = \lambda\gamma\left(\frac{\overline{p}_t(h) + \kappa P_t^N}{P_t^H}\right)^{-\sigma}\left(\frac{P_t^H}{P_t^T}\right)^{-\theta}\left(\frac{P_t^T}{P_t}\right)^{-\varepsilon} C_t, \tag{29}$$

$$y_t^{d*}(h) = c_t^{d*}(h) = (1-\lambda)\,\gamma\left(\frac{\overline{p}_t^*(h) + \kappa P_t^{N^*}}{P_t^{H^*}}\right)^{-\sigma}\left(\frac{P_t^{H^*}}{P_t^{T^*}}\right)^{-\theta}\left(\frac{P_t^{T^*}}{P_t^*}\right)^{-\varepsilon^*} C_t^*, \tag{30}$$

and where foreign profits are valued back in home country currency using the real exchange rate. where τ is a time-invariant tax on sales[24].

[23] In a model with capital $MC_{T,t}^n$ is equal to wages over the marginal product of labor, so that the optimal price setting can be also expressed as $\frac{p_t^N(n)}{P_t} = \frac{P_t^N}{P_t} = \frac{\sigma}{(\sigma-1)}\frac{W_t}{\alpha\frac{y_t^N}{L_t^N}}$

[24] We introduce this tax in order to eliminate the distortion generated by distribution services at the consumer price level in the steady state.

Each firm produces according to the following production function

$$y_t^T(h) = Z_t^T \left[N_t^T(h)\right]^{\alpha^T} \left[K_{t-1}^T(h)\right]^{1-\alpha^T} \tag{31}$$

where Z_t^T is the country-specific productivity shock to the tradable sector at time t and MC_t^T corresponds to the real marginal cost in units of aggregate goods. It can differ from the real marginal cost in the nontradable sector up to a constant if the labor and capital shares are different. The optimal-capital-output ratio is:

$$\frac{W_t L_t^T}{\alpha^T} = \frac{R_t^k K_{t-1}^T}{(1-\alpha^T)} \tag{32}$$

The optimal price settings at producer level, $\overline{p}_t(h)$ and $\overline{p}_t^*(h)$ are

$$\frac{\overline{p}_t(h)}{P_t} = \frac{\overline{P}_{H,t}}{P_t} = \frac{\sigma}{(\sigma-1)}\frac{1}{1-\tau}\left[\frac{(W_t)^{\alpha^T}\left(R_t^k\right)^{(1-\alpha^T)}}{\Phi^T Z_t^T} + \frac{\kappa}{\sigma}\frac{P_t^N}{P_t}\right], \tag{33}$$

$$\frac{\overline{p}_t^*(h)}{P_t^*} = \frac{\overline{P}_{H,t}^*}{P_t^*} = \frac{\sigma}{(\sigma-1)}\frac{1}{1-\tau}\left[\frac{(W_t)^{\alpha^T}\left(R_t^k\right)^{(1-\alpha^T)}}{\Phi^T Z_t^T}\frac{P_t}{P_t^*} + \frac{\kappa}{\sigma}\frac{P_t^{N^*}}{P_t^*}\right] \tag{34}$$

where $\Phi^T = (\alpha)^{\alpha^T}(1-\alpha^T)^{(1-\alpha^T)}$. The marginal cost for tradable goods varies as a function of the price of non-traded goods. Hence, the price setting of tradable goods at home will depend implicitly on the productivity shocks in the non-tradable sector. Under the presence of distribution costs the elasticity of demand for domestic goods is not the same at home and abroad, and firms will charge different prices in each market[25]. Note that optimal price setting implies deviations from the law of one price $\left(\overline{P}_t^H \neq \overline{P}_t^{H^*}\right)$ unless the degree of distribution margins does not exist, $\kappa = 0$.

2.4 Market Clearing

The market clearing condition in the tradable good sector at home is

$$Y_t^T = C_t^H + C_t^{H^*} + I_t^T \tag{35}$$

The market clearing for the nontradable good sector is

$$Y_t^N = C_t^N + I_t^N + \kappa_t \tag{36}$$

Aggregate output in terms of home goods is:

$$Y_t = \frac{P_t^T}{P_t}Y_t^T + \frac{P_t^N}{P_t}Y_t^N \tag{37}$$

[25] See Corsetti and Dedola (2005) for a detailed explanation of this issue. Selaive and Tuesta (2003a) also perform a quantitative analysis of a model with imperfect pass-through allowing for nominal price rigidities in the nontradable sector. They show how the imperfect pass-through generated by distribution services dampens the expenditure switching effect.

3 Simulation of the Model

We solve the model by taking log-linear approximation around a well defined steady state with stationary net foreign assets. We denote by $\widehat{X_t}$ as the percent deviations of a variable from its steady state values.

In what follows we will present some key equations to gain intuition about our results. Given the parameters and the structure of shocks we solve a system of linear difference equations using the Anderson and Moore´s solution algorithm.

3.1 Parametrization

The parameters utilized in our simulations are reported in table 1. Our benchmark parametrization is taken from CKM and Stockman and Tesar (1995). In particular, we set most of the parameters as in CKM, but some of them correspond to values used by Stockman and Tesar.

Shocks are assumed to follow an autoregresive process of the form $Z_t = Z_{t-1} + \varepsilon_t$ where $Z_t \equiv [Z_T, Z_{NT}, Z_T^*, Z_{NT}^*]$ and χ is a 4x4 matrix describing the autoregresive component of the disturbance. The disturbance are $\varepsilon_t \equiv \left[\varepsilon_{T,t}\ , \varepsilon_{NT,t}\ , \varepsilon^*_{T,t}\ , \varepsilon^*_{NT,t}\ \right]$. The structure of the shock process is taken from Stockman and Tesar (1995) and are reported in Table 1. We adopt the same utility function as CKM (2002),

$$U^h\left(C_t, N_t\right) = E_t\left[\sum_{s=t}^{\infty}\beta^{s-t}\left(\frac{1}{1-\rho}\left(C_t\right)^{1-\rho} - \frac{L_t^{1+\eta}}{1+\eta}\right)\right]$$

We set a quarterly discount factor, β, equal to 0.99, which implies an annualized rate of interest of 4%. For the coefficient of risk aversion parameter, ρ, we choose a value of 5 as in CKM. The inverse of the elasticity of leisure, η is set equal to 1.5. The value of the elasticity of substitution between traded and non-traded goods, ε, is taken from Stockman and Tesar (1995) and is set equal to 0.44. The value of the elasticity of substitution between traded goods, θ, is set equal to 1.5 as in CKM[26]. We perform sensitivity analysis regarding this parameter. The weight associated with traded versus non traded goods, γ, is set equal to 0.5 and it was calibrated taking into account the share of traded goods in the consumption bundle for U.S. We consider the same degree of home bias as the one implied in CKM and Heathcote and Perri (2002) such that $\lambda = 0.96$. For debt elasticity premium parameter δ, we choose 0.007 given recent evidence by Rabanal and Tuesta (2005) and Selaive and Tuesta (2003a, 2003b)[27].

For the intermediate goods producers we set the labor share $\alpha^N = \alpha^T = \alpha = 0.58$ following Stockman and Tesar (1995) and the depreciation rate $\delta = 0.021$ is taken from CKM. The latter implies an annual depreciation rate of 10 percent. Similarly, following CKM we consider an adjustment function of the form $\frac{b\left(\frac{I}{K}-\delta\right)^2}{2}$. We choose the parameter b so that the standard deviation of investment relative to the standard

[26] Obstfeld and Rogoff (2000) presents a survey regarding the empirical estimates of θ, suggest high values for this elasticity. Rabanal and Tuesta (2005) find out estimates of this parameter in the range between (0.5 and 0.95) in models relying in both producer currency pricing and local currency pricing assumptions.

[27] Selaive and Tuesta (2003a, 2003,b) estimates the implied risk-sharing condition that arises from the incomplete asset market structure and find out values between 0.004 and 0.01 of this elasticity. Complementary, Rabanal and Tuesta (2005) perform structural estimation of an incomplete asset markets model under different form os international pricing with nominal rigidities. Their findings give support for the presence of cost of bond holdings.

deviation of output is similar to the data (around 3 times). We choose a degree of monopolistic competition, σ, equal to 7.66 following Rotemberg and Woodford (1998), which implies an average mark-up of 15 percent over the marginal cost in a model without distribution services. We set $\tau = \tau^* = 1 - \frac{[1+\kappa/(\sigma-1)]}{1-\kappa}$ so that the law of one price at consumer level holds in the steady state. We set the distribution cost parameter, κ, equal to 0.5 which implies a margin of 50 percent of the retail price of consumer goods due to distribution costs[28].

3.2 Explaining the Consumption Real Exchange Rate Anomaly

3.2.1 Impulse Response Functions: Some Intuition

We can get some intuition of our quantitative results reported in the next section first by analyzing the IRFs following a positive domestic tradable productivity shock.

In Figure 1 we depict the responses to a 1 percent productivity shock in the tradable sector in the domestic economy which decays with an autoregressive coefficient of 0.95. We compare the dynamics of the benchmark model without distribution services (NDS) with respect to the one predicted in a model with distribution services (DS). The striking result is that both model economies predict negative comovement between the real exchange rate $\left(\widehat{Q}_t\right)$ and relative consumptions $\left(\widehat{C}_t^R\right)$ following the shock. Thus the productivity shock in the tradable sector leads to an increase in relative consumptions $\left(\uparrow \widehat{C}_t^R\right)$ vis-a-vis a real exchange rate appreciation $\left(\downarrow \widehat{Q}_t\right)$. Importantly, notice that the real exchange rate appreciation is amplified in a model with distribution services. Hence, distribution services by lowering the elasticity of demand makes relative prices more sensitive to shocks.

In the benchmark economy following the positive shock in tradable productivity, due to wealth effects domestic consumption increases, which is compensated with the decrease in investment ($\downarrow I_t$) and therefore $\left(\widehat{Y}_t > \widehat{C}_t + \frac{I}{Y}\widehat{I}_t\right)$, therefore, an asset accumulation occurs ($\uparrow b_t$). Foreign consumption also increases but less than the domestic one, so we observe an increase in relative consumptions$\left(\uparrow \widehat{C}_t^R\right)$. Wealth effects -due to the presence of nontraded goods- also induce a decrease in the labor supply in the tradable sector $\left(\downarrow \widehat{L}_t^T\right)$ and, consequently, an increase in real wages is observed$\left(\uparrow \widehat{W}_t\right)$. Prices in the tradable sector increase because wealth effects more than compensate the expected negative effect of tradable productivity over prices $\left(\uparrow \widehat{P}_t^H\right)$. Then, the increase in domestic prices generates an appreciation in the terms of trade $\left(\downarrow \widehat{T}_t = \widehat{P}_t^F - \uparrow \widehat{P}_t^H\right)$[29]. Since wages are homogeneous across sectors, wages in the nontradable sector also increases and we also observe an increase in the price of nontraded goods $\left(\uparrow \widehat{P}_t^N\right)$ which in turn causes a reduction in the relative price of tradable to nontradable goods $\left(\downarrow \widehat{R}_t\right)$[30]. Both effects, the appreciation in the terms of trade and the reduction in the relative price in nontraded to traded goods, cause an

[28] Burstein, Neves and Rebelo (2003) show that distribution costs are large and account for about 40-60 percent of the retail price in U.S.

[29] In our model a productivity shock in the tradable shock improves the terms of trade which is in line with the empirical VAR´s findings reported in Corsetti, Dedola and Leduc (2004)

[30] Moreover, this mechanism is called the Balassa-Samuelson effect which contributes towards an appreciation of the real exchange rate and switched demand from home to non-traded to traded goods.

appreciation of the real exchange. To illustrate the previous result, note that in our benchmark economy, without distribution services, the real exchange rate in log-linear form can be decomposed in the following way:

$$\widehat{Q}_t = (2\lambda - 1)\,\widehat{T}_t + (1-\gamma)\left(\widehat{R}_t - \widehat{R}_t^*\right) \tag{38}$$

where $T_t = \frac{P_t^F}{P_t^H}$ represents the terms of trade, and $R_t \equiv \frac{P_T}{P_{NT}}$ and $R_t^* \equiv \frac{P_T^*}{P_{NT}^*}$ correspond to the relative prices of traded to nontraded goods at home and abroad, respectively. The first term captures the traditional home-bias channel $(2\lambda-1)\,\widehat{T}_t$, and the second term accounts for the traditional Balassa-Samuelson effect, $(1-\gamma)\left(\widehat{R}_t - \widehat{R}_t^*\right)$[31]. Remarkably, in our benchmark calibration even with θ larger than one (1.5) a tradable productivity shock generates an improvement in the the terms of trade and an increase in the relative price of nontraded goods, so both effects tend to appreciate the real exchange rate as it is clear from equation (38).

How the model with distribution services can help to account for some international comovements? Interestingly, as despicted in Figure 1, the model with distribution services (DS) amplifies the dynamics of both the real exchange rate and the terms of trade, so we might expect to get more volatile international relative prices. Thus, distribution services reduces the effective price elasticity of aggregate import demand leading to a larger adjustment in international relative prices. The larger the appreciation the larger the wealth effect with respect to the benchmark case, and the model gets closer to the data in terms of both the *anomaly* and the volatility of relative prices. To give more intuition, in the the model with distribution services (DS) the real exchange rate dynamics can be decomposed as follows:

$$\widehat{Q}_t = \widehat{\Psi}_t^C + (2\lambda - 1)\,\widehat{T}_t + (1-\gamma)\left(\widehat{R}_t - \widehat{R}_t^*\right) \tag{39}$$

$$\widehat{\Psi}_t^C = \widehat{\Psi}_t^P + \frac{\kappa}{1-\kappa}\left(\widehat{R}_t - \widehat{R}_t^*\right) + \frac{\kappa}{1-\kappa}\left[(2\lambda-1)\,\widehat{T}_t\right] \tag{40}$$

Equation (39) shows how the real exchange rate can be decomposed once we account for deviations from the law of one price both at the border $\left(\overline{P}_t^H \neq \overline{P}_t^{H^*}\right)$ and at consumer level $\left(P_t^H \neq P_t^{H^*}\right)$. The first term in equation (39) $\Psi_t^c \equiv P_{H,t}^*/P_{H,t}$ captures the deviation from the law of one price at consumer level and arises because of the presence of distributive services. Its dynamics is represented in equation (40), where $\Psi_t^p \equiv \overline{P}_{H,t}^*/\overline{P}_{H,t}$ accounts for the deviations from the law of one price at the border. Notice that when $\kappa = 0$ the law of one price holds and we get back to the benchmark economy.

Importantly, it is also possible to establish a relation between the market rate, $T_t \equiv \frac{P_F}{P_H}$, and the terms of trade at producer level $ToT_t \equiv \overline{P}_{F,t}/\overline{P}_{H,t}^*$.

$$\widehat{ToT} = \frac{1}{1-k}\widehat{T}_t - \widehat{\Psi}_t^P \tag{41}$$

When $\kappa = 0$, there is perfect pass-through and the law of one price holds, $\widehat{T}_t = \widehat{ToT}_t$ and $\widehat{\Psi}_t^p = \widehat{\Psi}_t^c = 0$.[32]

[31] Similar expression is derived in Benigno and Thoenissen (2004)

[32] Observe that $\widehat{\Psi}_t^c$ could be associated to an analogous variable derived in Monacelli (2005) that measures the *law of one price gap*. This author incorporates an imperfect pass-through mechanism by considering that domestic importers face a pricing decision similar to the domestic producer, setting prices directly in local currency.

3.2.2 Non Tradable goods and the Anomaly

As shown in the impulse response functions (IRFs), nontraded goods plays a key role in amplifying wealth effects. In order to clarify the previous result, and for the sake of exposition, let us assume there is no investment dynamics in a benchmark model. Then, the net foreign assets accumulation equation and the implied risk-sharing condition can be re-expressed as follows[33]:

$$\beta b_t - b_{t-1} = (1-\lambda)\gamma\widehat{Q}_t - 2(1-\lambda)\gamma\lambda(\theta-1)\widehat{T}_t + (1-\lambda)\gamma(1-\varepsilon)(1-\gamma)\left(\widehat{R}_t - \widehat{R}_t^*\right) - (1-\lambda)\gamma\left(\widehat{C}_t - \widehat{C}_t^*\right) \tag{42a}$$

$$\rho E_t\left(\left(\widehat{C}_{t+1} - \widehat{C}_{t+1}^*\right) - \left(\widehat{C}_t - \widehat{C}_t^*\right)\right) = E_t\left(\widehat{Q}_{t+1} - \widehat{Q}_t\right) - \delta b_t \tag{43}$$

It is well know that in a model with tradable goods only ($\gamma = 1$), symmetric preferences $\lambda = 1/2$, $\rho = 1$, and with a unitary elasticity of substitution between tradable goods ($\theta = 1$) the adjustment in the terms of trade is sufficient to yield perfect risk sharing. In that case, there is not need for any adjustment in the current account. To see that, for simplicity, let us assume that $\gamma = 1$,$\lambda = 1/2$ and $\theta = \rho = 1$. Under the previous parametrization the real exchange is constant and both the NFA accumulation and risk-sharing conditions boil down to

$$b_t - \beta b_{t-1} = 1/2\widehat{C}_t^R \tag{44a}$$

$$E_t\left(\widehat{C}_{t+1}^R - \widehat{C}_t^R\right) = -\delta b_t \tag{45}$$

where $\widehat{C}_t^R = \left(\widehat{C}_t - \widehat{C}_t^*\right)$ represents relative consumptions. Given the assumption of $\phi(.)$, δ should be positive and given that b_t is a predetermined variable with initial value $b_{-1} = 0$, the NFA position is zero at every period. Therefore in this scenario we achieve perfect risk sharing.

In contrast, once we introduce non traded goods, even under the previous parameter values, risk-sharing is broken down. Moreover, the real exchange rate is not anymore constant an depends upon the relative price of traded to non-traded goods across countries. Thus, equations ($42a$) and (43), after replacing the real exchange rate dynamics into the NFA accumulation equation, can be re-written as:

$$b_t - \beta b_{t-1} = (1-\lambda)\gamma\left[(2-\gamma-\varepsilon)\widehat{R}_t^R - \widehat{C}_t^R\right] \tag{46a}$$

$$E_t\left(\widehat{C}_{t+1}^R - \widehat{C}_t^R\right) = (1-\gamma)E_t\left(\widehat{R}_{t+1}^R - \widehat{R}_t^R\right) - \delta b_t \tag{47}$$

where $\widehat{R}_t^R = \widehat{R}_t - \widehat{R}_t^*$ stands for the relative price of tradable to nontraded goods across countries. Notice that after a productivity shock in the traded sector the relative price of home non traded goods increases

[33] The characterization of this incomplete asset market structure maintains the gap between growth rate of relative consumptions that emerges in the incomplete asset structure specified in CKM but, in addition, the dynamic of the net foreign assets plays an explicit role. As long as there is either asset accumulation or asset decumulation, the real exchange rate will be affected by the net foreign asset position and, therefore, the link between the real exchange rate and relative consumptions will be broken down. In Selaive and Tuesta (2003a,2003b) we test the novel risk-sharing condition, and we find that growth factors of consumption and real exchange rates behave in a manner that may be consistent with a significant role for the net foreign asset position. See Rabanal and Tuesta (2005) for a structural estimation using bayesian techniques.

$\left(\downarrow \widehat{R}_t^R \text{ goes down}\right)$ which can be consistent with an increase in relative consumptions and a real exchange rate appreciation.

Furthermore, we can take the extreme case of market incompleteness, called financial autarky. Under financial autarky the NFA position is zero at all times. Then, expression (46*a*) now reads:

$$\widehat{C}_t^R = \left[(2-\gamma-\varepsilon)\,\widehat{R}_t^R\right] \tag{48a}$$

$$\widehat{C}_t^R = \frac{(2-\gamma-\varepsilon)}{(1-\gamma)}\widehat{Q}_t \tag{48b}$$

From the above equation we can see the key role of non tradable goods in a clearer way. Notice that even when $\widehat{C}_t^R$ and $\widehat{Q}_t$ moves in the same direction, we still can obtain a negative correlation between the real exchange rate and relative consumptions. In particular, when $2-\gamma<\varepsilon$ we can obtain a negative correlation even with a value of $\theta=1$. Furthermore, expression (48*b*) holds regardless of other real frictions or nominal rigidities in the economy. High values of ε will generate negative correlations between relative consumptions and the relative price of traded to nontraded goods. It is worthwhile to mention that the incomplete markets model is an intermediate case between financial autarky and complete markets.

3.3 Quantitative Properties of the Model

The results of our simulations are summarized in Table 2. We evaluate the unconditional correlation between real exchange rate and relative consumptions as well as some other statistics. The first column of the table 2 reports H-P filtered statistics for the data from quarterly time series taken from CKM (2002) and own calculations.

Let us first focus on the benchmark economy without distribution services (second column of table 2, *NDS*). Remarkably, the economy with non tradable goods and incomplete markets can successfully account for the *consumption real exchange rate anomaly*. We obtain a negative value of -0.32, against the data -0.45. Furthermore, both the terms of trade and the real exchange rate exhibit a volatility closer to the one observed in the data: 3.33 and 3.18, respectively. We also report a positive correlation between the real exchange rate and the terms of trade (0.97)[34]. Importantly, the real exchange rate is more volatile than the terms of trade, a result which is consistent with the data. In fact, it is well know that a model with tradable goods only and home bias will deliver real exchange rates less volatile than the terms of trade[35].

Consider now the rest of statistics for the benchmark economy reported in Table 2. Consumption is less volatile in the model than in the data, because when $\rho=5$, a relatively high adjustment cost parameter is needed to make investment to have a volatility above 3. The cross-country correlation of output (0.44) is

[34] A positive sign of this correlation is a key feature in the data. A model with tradable goods only and home bias will unambiguosly predict a positive correlation between the real exchange rate and the terms of trade. Instead, in a model with nontradable goods this is no necessarily the case. In our model economy, conditional to a productivity shock in the tradable sector, both the terms of trade and the relative prices of nontraded goods move in the same direction and the positive commovement between the real exchange rate and the terms of trade are consequent.

[35] In a model with only tradable goods the real exchange rate can we expressed as follows $\widehat{Q}_t=(2\lambda-1)\,\widehat{T}_t$. From this expression it is straightforward to see that the real exchange rate will be always less volatile than the terms of trade.

very close to that observe in the data (0.49) while the cross-correlation of investments is higher than the one reported in the data. Interestingly, the cross-correlation of consumptions (0.39) gets close to that of the data (0.32) and is smaller to the correlation of output across countries. Thus, a model with nontraded good does much better than standard real business cycle models in this dimension. In particular, standard real business cycle models that deliver very low volatility of the real exchange rate also predict a higher correlation of consumption across counties with respect to that of outputs (either under the bond economy or complete markets). Finally, the model does a good job at accounting for countercyclical next exports. Their correlation with output is -0.26 against -0.12 in the data.

Consider now the benchmark economy with distribution services. Overall, the statistics are quite similar, yet the model delivers a much more volatile real exchange rate and terms of trade, getting closer to the data. Distribution services decrease the import demand elasticity, making relative prices more volatile. Other moments -including the one referred to the *anomaly*- are not significantly affected.

In a nutshell an incomplete and imperfect assets market structure along with the nontraded goods help resolve the *anomaly* in a model without distribution services. Yet, the model with distribution services helps in getting closer to the data in terms of relative price volatilities.

3.4 Sensitivity Analysis

Here we examine the sensitivity of our findings by varying assumptions about five of the benchmark model´s features. We evaluate the importance of nontraded goods by excluding them from the model. Remarkably, the simulated exercise delivers a positive and high value of the correlation between the RER and relative consumptions, therefore we conclude that a model with tradable goods only is not able to explain the *anomaly*. We consider a complete asset market structure and we find, as expected, a unitary correlation between the real exchange rate and relative consumptions. We consider non-separable preferences and find little change. We perform sensitivity analysis with respect to the elasticity of substitution between tradable goods, (θ), and find that the smaller the elasticity the larger the volatility of the international relative prices. Finally, we add stickiness to the model along with an endogenous taylor-type rule and we find that the volatility of relative prices and employment increases.

3.4.1 Tradable Goods Only $(\gamma = 1)$

As it was documented in the previous section, a key element in explaining the main features of the real exchange rate dynamics is the presence of nontradable goods. In order to highlight their importance, in column 11 we report the statistics for the benchmark model shutting down the nontradable goods sector $(\gamma = 1)$. Worthnoting, this model is similar to the one proposed by CKM but without nominal rigidities. The model delivers a correlation between the real exchange rate and relative consumptions close to one (similar finding has been reported by CKM). Wealth effects are almost inhibited once non tradable goods are absent. In addition, since the law of one price holds the volatilities of the real exchange rates and terms of trade decrease dramatically (0.40 and 0.43, respectively). It seems that any theory of real exchange rate determination can be successful at matching the data without considering non traded goods.

3.4.2 Complete Markets

The complete markets assumption implies the following relationship between the real exchange rate and relative consumptions in log linear form. The expression below replaces the implied risk-sharing condition in the benchmark economy (equation 43)

$$\rho\left(\widehat{C}_t - \widehat{C}_t^*\right) = \widehat{Q}_t \tag{49}$$

Given the above relationship, unambiguously, de model will deliver a unitary value for the correlation between the real exchange rate and relative consumptions. The results are reported in column 4 in table 2. Again the volatility of the real exchange rate, with respect to the benchmark economy, decreases dramatically (from 3.33 to 0.56). In addition, the complete market model delivers a highly procyclical net exports which runs against with what we observe in the data. In contrast with Baxter and Crucini (1995) and Heathcote and Perri (2002) there are important differences between complete markets and the incomplete markets models once non tradable goods are taken into account. Results under complete markets make evident the difficulties that Stockman and Tesar (1995) would have faced in explaining the *anomaly.*

3.4.3 Non-Separable Preferences

Now we consider what would happen to the benchmark model´s prediction if we make a change in the form of preferences. Here we follow Stockman and Tesar (1995) by assuming the same type of preferences:

$$U^h\left(C_t, N_t\right) = E_t\left[\sum_{s=t}^{\infty}\beta^{s-t}\frac{1}{1-\rho}\left(C_t\right)^{1-\rho}\left(1-L_t\right)^{\eta}\right] \tag{50}$$

Overall, business and international price statistics delivered by the simulated model do not change significantly (columns 5 & 6, of Tabla 2), although the model reports a higher volatility of both the real exchange rate and the terms of trade compared to the benchmark model.

3.4.4 Elasticity of Substitution Between Tradable Goods (θ)

In this section we evaluate the role of the intertemporal elasticity between tradable goods. We perform a sensitivity analysis under two values of the parameter θ, a low elasticity (0.9) and an high elasticity (6.0). The results are reported in columns 7 & 8. Recall that this parameter determines the degree to which the terms of trade and real exchange rate respond to productivity shocks. *Ceteris paribus*, the larger the elasticity, the lower the terms of trade and real exchange rate volatility. With low and high values of this elasticity, the model still performs well with respect to the *anomaly.* When markets are incomplete, the effect of the terms of trade over the NFA is shaped by the elasticity of substitution between home and foreign traded goods. Clearly, θ is a crucial parameter, and as it becomes larger it exacerbates the net foreign assets accumulation breaking the link between the real exchange rate and relative consumptions. With $\theta = 6$, the cross-correlation between the RER and relative consumption is also negative and smaller than in the benchmark case (-0.76 versus -0.32, respectively). Yet, a larger elasticity implies a stronger adjustment in quantities rather than in prices, so that the model predicts a decrease in the volatility of international prices for larger values of this elasticity. Thus, the volatility of the RER decreases from 3.33 in the benchmark economy to 2.04 in a high elasticity scenario.

3.4.5 Sticky Prices and Monetary Policy

Finally, we examine what happens when we introduce nominal rigidities and monetary policy. Instead of having real bonds we define the economy in terms of nominal bonds, hence the euler equations change accordingly (see Selaive and Tuesta 2003a)[36]. For simplicity we only assume sticky prices -a la calvo- in the nontradable sector. The new Keynesian Phillips curve adopts the following form:

$$\pi_t^N = \varpi \widehat{mc}_t + \beta E_t \pi_{t+1}^N \tag{51}$$

where $\varpi = (1 - \xi\beta)(1 - \xi)/\xi$ and ξ is the probability of not adjusting prices. $\widehat{mc}_t$ is the log deviation of the real marginal cost. In characterizing the monetary policy, we assume that the central bank follows a taylor-type rule setting the short term interest rate as a function of deviations of expected nontradable inflation and GDP from its steady state value

$$i_t = \rho i_{t-1} + (1-\rho)\gamma_\pi E_t\left(\pi_{t+1}^N\right) + (1-\rho)\gamma_y \widehat{Y}_t \tag{52}$$

We parameterize the policy rule following Rabanal and Tuesta (2005): $\rho = 0.87$, $\gamma_\pi = 1.59$, $\gamma_y = 1.08$. We set the parameter $\xi = 0.66$ which is relatively standard in the literature.

Columns 9 & 10 in table 2 report the implications of stickiness and an endogenous taylor rule under both models: *NDS* and *DS*. Overall, the results are not altered significantly with respect to flexible prices models. Moreover, both models are still able to account for the *anomaly.* Importantly, in both sticky price models the volatility of the international prices are higher than those obtained in the flexible price models. It is worth to mention that the model with distribution services generates *intermediate degrees of pass-through* and for instance this is the only model which is able to account for the differences in the cross-corrrelation between the RER and the terms of trade at consumer level and the RER and the terms of trade at producer level, respectively (last two rows of table 2).

4 Conclusions

A central puzzle in international macroeconomics is why fluctuations of the real exchange rate are so volatile while relative consumption is not, a fact that contradicts efficient risk-sharing. Standard complete and incomplete markets models with *tradable goods only* predict a high and positive cross-correlation between the real exchange rate and relative consumptions while in the data we observe the opposite. The

[36] Lubik and Schorfheide (2005) have estimated a DSGE two-country model with nominal rigidities and local currency pricing and complete markets. Rabanal and Tuesta (2005) evaluates the merits of incomplete markets and the role of monetary policy in accounting for the real exchange rate dynamics. They find the incomplete markets structure to be crucial and monetary shocks to have less importance. in explaining the RER dynamics.

failure of these models to explain the data in this dimension is referred by CKM *the consumption real exchange rate anomaly* or Backus and Smith´s puzzle in a context of an IRBC model. Certaintly, as shown in CKM, wealth effects were very small to break ties between the real exchange rate and relative consumptions.

In this paper we have taken a step toward solving the *anomaly.* First, we highlight the need to combine incomplete markets and non traded goods in a standard IRBC model in order to account both for the negative comovement between the real exchange rate and relative consumptions and for the volatility of the real exchange rate. The presence of non tradable goods generates sizeable wealth effects so that NFA movements gather a decrease in the relative price of tradable to nontradable, the terms of trade and a real exchange rate appreciation.

Remarkably, in our simulations we also consider an elasticity of substitution between tradable goods larger than one and the model still perform reasonable well in all dimensions. Thus, due to the presence of nontraded goods, the standard paradigm that movements in terms of trade are sufficient to yield perfect risk sharing is broken down. Following, we evaluate to what extent distribution services adds more volatility to the international relative prices and, remarkably, distribution services add volatility to both the real exchange rate and the terms of trade.

Recent empirical evidence have put into debate the success of estimated structural open economy DSGE models in fitting the data and in particular de real exchange rate dynamics. Lubik and Schorfheide (2005, 2006) and Rabanal and Tuesta (2005) have started to estimate small-scale NOEM economy models with data for US-Europe. Justiniano and Preston (2004, 2006) perform a structural estimation fora small open economy. Walque Smets and Wouters (2005) estimate a medium sized two-country model for the USA and Europe. All previous contributions consider models with tradable goods only. Their estimations, with traditional structural shocks, find hard to account for the real exchange rate dynamics. Thus our findings suggest that other modeling structure in particular the introduction of non traded goods could help to improve the fit of estimated international models. Further research and more attention should be paid to modeling and to estimate movements in the real exchange rate that arise from movements in the relative prices of traded to nontraded goods.

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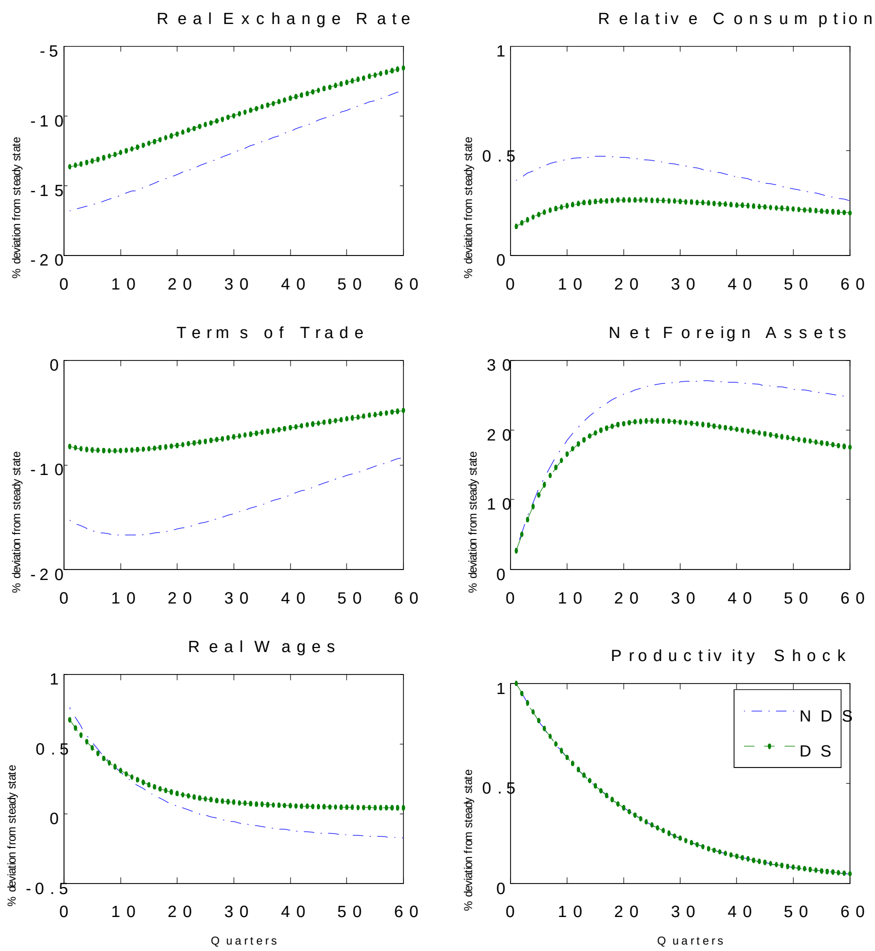

Impulse Responses: Domestic Prodcutivity Shock in the Tradable Sector

Table 1
Benchmark Parametrization

Preferences	$\beta = 0.99$; $\sigma = 7.66$; $\eta = 1.5$; $\rho = 5$; $\theta = 1.5$; $\varepsilon = 0.44; \gamma = 0.5; \lambda = 0.96$
Technology shocks	Autocorrelation matrix, $\Omega = \begin{bmatrix} 0.154 & 0.040 & -0.199 & 0.262 \\ -0.150 & 0.632 & -0.110 & 0.125 \\ -0.199 & 0.262 & 0.154 & 0.040 \\ -0.110 & 0.125 & -0.015 & 0.632 \end{bmatrix}$
	Var-cov matrix, $V = \begin{bmatrix} 3.62 & 1.23 & 1.21 & 0.51 \\ 1.23 & 1.99 & 0.51 & 0.27 \\ 1.21 & 0.51 & 3.62 & 1.23 \\ 0.51 & 0.27 & 1.23 & 1.99 \end{bmatrix}$
Distributions costs	Parametr κ was set such a margin of 50% over marginal cost
Incomplete Markets	$\delta = 0.007$

Table 2

Exchange Rates, prices and business cycle statistics

				Sensitivity Analysis on the benchmark setting							
	Data[a]	Benchmark Parametrization		Complete Markets	Non Separable preferences		Tradable Substitution		Sticky Prices		Only Tradables
							θ=0.9	θ=6			
Variable		NDS	DS	NDS	NDS	DS	NDS	NDS	NDS	DS	NDS
Standard Deviation											
Real Exchange Rate	3.33	3.33	4.94	0.56	5.06	5.43	3.77	2.04	4.75	5.75	0.40
Terms of trade	1.95	3.18	3.79	1.03	4.77	4.25	3.18	2.01	4.25	4.78	0.43
Consumption	0.78	0.11	0.09	0.11	0.17	0.06	0.10	0.09	0.10	0.11	0.10
Employment	0.98	0.03	0.10	0.03	0.25	0.27	0.08	0.08	0.05	0.07	0.15
Investment	3.96	3.13	3.19	3.15	3.01	3.26	3.21	3.05	3.15	3.16	3.69
Cross-correlations between Foreign and domestic											
Output	0.60	0.44	0.43	0.87	0.45	0.53	0.25	0.36	0.55	0.59	0.59
Consumption	0.38	0.39	0.42	0.45	0.47	0.76	0.44	0.41	0.45	0.49	0.64
Investment	0.33	0.47	0.46	0.45	0.46	0.44	0.38	0.31	0.40	0.41	0.64
Cross-correlation											
Net exports and output	-0.41	-0.26	-0.21	0.48	0.56	0.65	-0.46	-0.11	-0.51	-0.38	0.45
RER and terms of trade-consumer level	0.60	0.97	0.98	0.77	0.98	0.98	0.98	0.97	0.84	0.84	1.00
RER and terms of trade-producer level	0.45	0.97	0.97	0.77	0.98	0.99	0.99	0.97	0.84	0.72	1.00
RER and relative consumption	-0.35	-0.32	-0.28	1.00	0.04	-0.66	-0.58	-0.76	-0.58	-0.47	0.99

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