Can producer currency pricing models generate volatile real exchange rates?

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Abstract

Models in which prices are sticky in the currency of the producer have difficulty in generating volatile real exchange rates. Because of expenditure-switching, the response of the real exchange rate to the exogenous shocks is moderate. However, if both the elasticities of substitution between traded and nontraded and between Home and Foreign traded goods are set at a sufficiently low level, then a general equilibrium model with full producer currency pricing can generate real exchange rate that are as volatile as in the data.

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1 Introduction

The high volatility of the real exchange rate is one of the most important facts in international macroeconomics. In their seminal work, Chari *et al.* (2002) show that it is possible to reproduce quantitatively the empirical volatility of the real exchange rate in a dynamic stochastic general equilibrium model with sticky-prices, provided certain conditions on preferences are satisfied and prices are held fixed for at least one year.

Chari *et al.*'s result crucially depends on their assumption of full local currency pricing (LCP). However, reality may lie somewhere between LCP and the other extreme, producer currency pricing (PCP). Hence, the ability of models with full PCP to mimic the volatility of the real exchange is a question worth investigating, because such analysis provides useful indications for models which assume a mixture of PCP and LCP.

This paper investigates quantitatively a simple yet effective way to generate high real exchange rate volatility with full PCP. By choosing low values for two elasticities of substitution (between traded and nontraded and between Home and Foreign traded goods) it is possible to obtain highly volatile real exchange rates in a model with full PCP. The values that the elasticities are required to take in this set-up depend on the specific empirical estimate of the standard deviation of the real exchange rate, but they may be considerably lower than one. This result suggests that, whenever a mixture of LCP and PCP is assumed on the grounds of "realism", then the substitution elasticities must take on values that are sensibly lower than those used in full LCP models.[1]

2 The model

The model is akin to the PCP model of Obstfeld and Rogoff (1995), but it also includes several features that have been introduced more recently. Price rigidity is modelled *à la* Calvo (1983), and a small cost of holding bonds ensures that the model is stationary. Moreover, the calibrated model includes the features that, according to Chari *et al.* (2002), are crucial for generating high real exchange rate volatility: separable preferences, high risk aversion, and price-stickiness of at least one year.[2]

[1] Obstfeld and Rogoff (2005) note that calibrated models often assume elasticities that are higher than or equal to one, but several empirical studies have suggested values considerably lower than one.

[2] I do not, however, assume that all goods are traded, as in Chari *et al.* Their assumption is motivated by their finding that fluctuations in the price of nontraded goods have only a

The world economy consists of two countries, named Home and Foreign, each of them producing both traded and non-traded goods. In each country and sector there exists a continuum of monopolistic firms, each of them producing a single differentiated good. The firms and the goods they produce are indexed by $f_{TH} \in [0,1]$ for the Home traded sector and $f_N \in [0,1]$ for the Home nontraded sector. Differentiated goods are imperfect substitutes in consumption.

The Home and Foreign countries are assumed to be symmetric, so only the equations describing the Home country will be presented here.

2.1 Households

The utility of the representative household in the Home country is given by:

$$U_0 = E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{C_t^{1-\sigma}-1}{1-\sigma} + \frac{\chi}{1-\varepsilon} \left(\frac{M_t}{P_t}\right)^{1-\varepsilon} + \kappa \cdot \frac{\left(1-h_{TH,t}-h_{N,t}\right)^{1-\omega}}{1-\omega} \right] , \quad (1)$$

the variable C is an aggregate consumption basket having price P, M are nominal money balances, and $h_{TH} = \int_0^1 h_{TH}(f_{TH})\, df_{TH}$ and $h_N = \int_0^1 h_N(f_N)\, df_N$ are total hours supplied by the household to the traded and the non-traded sectors respectively.

Preferences over traded and non-traded goods, and over Home and Foreign-produced traded goods, are described by CES aggregators:

$$C_t = \left[(1-\gamma)^{\frac{1}{\phi}} \left(C_{T,t}\right)^{\frac{\phi-1}{\phi}} + \gamma^{\frac{1}{\phi}} \left(C_{N,t}\right)^{\frac{\phi-1}{\phi}} \right]^{\frac{\phi}{\phi-1}} , \quad (2)$$

$$C_{T,t} = \left[(1-\delta)^{\frac{1}{\theta}} \left(C_{TH,t}\right)^{\frac{\theta-1}{\theta}} + \delta^{\frac{1}{\theta}} \left(C_{TF,t}\right)^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}} . \quad (3)$$

The variables C_N, C_{TH} and C_{TF} are themselves CES aggregators of differentiated varieties, with the same elasticity of substitution. The law of one price holds for differentiated traded goods varieties. The price indices (in Home currency) P, P_T, P_N, and P_{TH}, and the Foreign price P_{TF}^* (in Foreign currency) are defined in the standard way, as the minimal expenditure needed to buy one unit of the corresponding consumption aggregator.

The household's period-t budget constraint is given by:

negligible role in explaining the variance of the real exchange rate, but Betts and Kehoe (2006) showed that this finding cannot be generalised to all countries.

$$B_t P_{T,t} + \frac{1}{2}\frac{\nu}{C_0} B_t^2 P_{T,t} + M_t \leq (1 + r_{t-1}) B_{t-1} P_{T,t} + M_{t-1} + W_t h_{TH,t} + W_t h_{N,t} +$$
$$+ TR_t + \int_0^1 \Pi_{TH,t}(f_{TH})\, df_{TH} + \int_0^1 \Pi_{N,t}(f_N)\, df_N + R_t - P_t C_t \ . \qquad (4)$$

The variable B denotes an internationally traded bond, denominated in units of the Home traded consumption index. As in Benigno (2001), the household must pay a cost for holding or issuing bonds. I assume that the cost is given by a quadratic function,[3] governed by the positive parameter ν, and that it is reimbursed to the household in the form of lump-sum transfers R. The variable r is the real interest rate, W is the wage rate, the same in both sectors, and TR are transfers from the government. Finally, $\Pi_{TH}(f_{TH})$ and $\Pi_N(f_N)$ are the profits from firms producing traded and non-traded goods respectively.

2.2 Government and firms

The government runs a balanced budget in each period: $M_t - M_{t-1} = TR_t$. Money is exogenous.

The production function of a traded sector firm is given by:

$$y_{TH,t}(f_{TH}) = z_{TH,t} \cdot h_{TH,t}(f_{TH})$$

where $y_{TH,t}(f_{TH})$ is the demand for variety f_{TH} , and z_{TH} represents exogenous technology. The production functions in the other sectors are analogous.

Fluctuations are caused by shocks to the exogenous, zero-mean AR(1) processes which govern technology and the growth rates of nominal money in both countries.

3 Solution and calibration

The model is log-linearised around a deterministic steady state and solved numerically.

I consider a benchmark parametrization, and then conduct sensitivity checks. The benchmark parametrization is summarised by Table 1, and it reflects common choices made in the literature.[4]

[3] C_0 denotes the steady-state value of consumption.

[4] The parameters and functional forms describing the Home and Foreign economies are assumed to be the same, but the weight assigned to Home-produced goods in the Foreign

The parameter σ is the same as in Chari *et al.* (2002).[5] Given σ, ε is chosen so that the consumption elasticity of money demand is equal to 1, as in Chari *et al.*.[6] Starting from the assumption that in the steady state the fraction of time spent working is equal to 0.31,[7] the parameter ω is then calibrated so that in the steady state the Frisch elasticity of labour supply[8] is equal to 1.

The parameters describing the exogenous processes are assumed to be the same in both countries. The parameters of the technology processes are taken from Chari *et al.*, and the parameters of the money growth processes are obtained by running a regression on HP-filtered M1 growth rates, using US data from 1981:1 to 2005:2.[9]

4 Results

The real exchange rate is defined as the ratio of Foreign prices over Home prices, expressed in the same currency:

$$RER_t \equiv \frac{e_t \cdot P_t^*}{P_t} \;, \tag{5}$$

where e is the nominal exchange rate. An increase (fall) in this quantity is a "depreciation" ("appreciation").

Figures 1 and 2 show the responses of RER to the shocks. The benchmark parametrisation is held constant and only the elasticities θ and ϕ vary between the two figures. The benchmark parametrisation is symmetrical and so are the responses to the Home and Foreign shocks.

Consider, for example, a positive Home monetary shock. Its direct effect on (5) is the nominal depreciation of the Home currency, which in turn induces two sorts of expenditure-switching effects. First, the nominal depreciation increases the competitiveness of Home traded goods relative to Foreign traded goods. Secondly, since the price of imports $e \cdot P_{TF}^*$ increases, the nominal depreciation decreases the relative price of nontraded goods, P_N/P_T, in the Home country. Hence, international demand is switching

traded consumption basket is equal to $1-\delta$, to reflect the same degree of home-bias in both countries.

[5] The calibration of χ is irrelevant for the log-linearised solution of the model.

[6] Sensitivity checks show that the value of ε has a very small impact on the volatility of the real exchange rate.

[7] The parameter κ can be calibrated so that the steady state of the model possesses this property.

[8] The Frisch elasticity of labour supply in the steady state is equal to $\frac{1}{\omega}\frac{1-0.31}{0.31}$.

[9] M1 data is from the OECD's Main Economic Indicators.

away from Foreign traded goods, and Home domestic demand is switching away from traded goods. To achieve equilibrium in all markets, the former expenditure-switching effect is absorbed by a fall[10] in P_{TF}^{*} , the latter effect by an increase in P_N. As a result, the Home CPI P increases and the Foreign CPI P^* decreases, moderating the response of RER to the shock. With low θ and ϕ, both expenditure-switching effects are more modest and the response of the real exchange rate to monetary shocks is sensibly magnified.[11] Low values for θ and ϕ also magnify the response of the real exchange rate to technology shocks.

Figure 3 illustrates the quantitative impact of both elasticities on the standard deviation of the real exchange rate over the standard deviation of output. The empirical estimates of this ratio vary in the literature: according to Chari *et al.* (2002) it is equal to 4.6, but Corsetti *et al.* (2005) report a value of 3.04 (US data). Nonetheless, both estimates can be successfully replicated by a PCP model if the two elasticities θ and ϕ are set at a sufficiently low level. For example, with both elasticities approximately equal to 0.57 the standard deviation of the real exchange rate in the model is equal to Chari *et al.*'s estimated value. Notice that with $\theta = 1.5$, as in Chari *et al.*, not even Corsetti *et al.*'s lower estimate can be replicated by the model.

Finally, sensitivity checks[12] show that the negative slope of the isoquants in Figure 3 is robust to changes in parameter values. Hence, both elasticities affect the volatility of the real exchange rate in all departures from the benchmark parametrisation.

[10] Meanwhile, in the Foreign country the nominal depreciation decreases the cost of imports and reduces the attractiveness of nontraded goods, so Foreign nontraded goods prices fall too.

[11] This occurs also because low elasticities tend to increase the response of the nominal exchange rate after a monetary shock.

[12] Available on request.

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Table 1: Home and Foreign Parametrization

β	Discount factor	0.99
σ	Risk aversion for consumption	5
ε	Elasticity of marginal utility of real money balances	5
ω	Elasticity of marginal utility of leisure	2.226
γ	Weight of nontraded goods in total consumption	0.70
δ	Weight of Foreign goods in Home traded consumption	0.30
	($1-\delta$ is the weight of Home goods in Foreign traded consumption)	
ν	Intermediation cost	0.0005
φ	Probability of not changing prices	0.75
η	Elasticity of substitution among differentiated goods	7.88
Exogenous processes:		
	Money growth: AR coefficient = 0.50; std. deviation = 0.009	
	Technology (both sectors): AR coefficient = 0.95; std. deviation = 0.007	