Nontradable Goods, Market Segmentation, and Exchange Rates*

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Abstract

Empirical evidence suggests that international markets, in general, and international markets for tradable goods, in particular, are highly segmented. Nontradable goods, both in the form of final consumption goods and as an input into the production of final tradable goods, are likely to be an important aspect of market segmentation across countries. In this paper we explore the role of nontradable goods (in final consumption and in retail services) for exchange rate variability in the context of an otherwise standard open-economy macro model. Our quantitative study suggests that nontradable goods increase the volatility of exchange rates by about 50 percent compared to the model without nontradable consumption goods or retail services and lower the correlation of exchange rates with other macro variables. In addition, our setup allows us to disentangle the properties of alternative pricing mechanisms that are standard in the open-economy macro literature.

Keywords: exchange rates; nontradable consumption goods; retail services

JEL classification: F3, F41

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1 Introduction

The empirical evidence regarding international relative prices at the consumer level suggests that arbitrage in international markets, in general, and international markets for tradable goods, in particular, is not rapid and that these markets are highly segmented. Nontradable goods, both in the form of final consumption goods and as an input into the production of final tradable goods, are likely to be an important aspect of market segmentation across countries for at least two reasons. First, international price differentials for these goods are not subject to international arbitrage. Second, nontradable goods represent a large proportion of GDP. In the U.S., for example, consumption of nontradable goods represents about 40% of GDP while retail services represents about 20%.[1]

In this paper we explore the role of nontradable goods (in final consumption and in retail services) in exchange rate behavior in the context of an otherwise standard open-economy macro model. Our quantitative study suggests that nontradable goods increase the volatility of exchange rates by about 50 percent compared to the model without either consumption of nontradable goods or nontradable retail services. In addition, we find that alternative assumptions regarding the currency in which firms price their goods are virtually inconsequential for the properties of aggregate variables in our model, other than the terms of trade.

We build a two-country model in which households consume final tradable and non-tradable goods. In our model, consumer markets for tradable goods are segmented across countries due to the presence of nontradable retail services in the production of final tradable consumption goods. In addition to retail services, these goods require the use of local and imported intermediate tradable goods. Intermediate tradable goods and nontradable goods are produced using local labor and capital services. We calibrate the shares of retail services, nontradable consumption goods, and trade in GDP to observed U.S. averages.

We find that the presence of nontradable goods (as retail services or nontradable consumption goods) plays an important role in the properties of exchange rate fluctuations

[1] These numbers are computed as the average share of personal consumption of services in private GDP from 1973 to 2004 and the average share of wholesale and retail services and transportation in private GDP from 1987 to 1997.

implied by the model. The presence of nontradable goods substantially increases the volatility of nominal and real exchange rates relative to the volatility of GDP. Consistent with the data, the increase in real exchange rate volatility is not accounted for by higher volatility of the relative price of nontraded relative to traded goods across countries, but rather by higher nominal exchange rate volatility.

The discussion of the properties of relative international prices has been closely tied with a discussion on the nature of the pricing decisions by firms.[2] The slow pass-through of exchange rate changes to consumer prices suggests that prices of imported goods are sticky and set in the currency of the consumer. This pricing mechanism is in sharp contrast with that of conventional open-macro models, in which imports are priced in the currency of the seller. Our setup allows us to disentangle the properties of alternative pricing mechanisms that are standard in the open-economy macro literature. We find that different assumptions regarding the pricing decisions of firms are virtually inconsequential for the properties of aggregate variables in our model, other than the terms of trade. Our model implies that the terms of trade behave more in line with the data under producer currency pricing. However, other than the terms of trade, we find that our model economy behaves quite similarly whether firms producing intermediate traded goods price their goods in the currency of the seller or of the buyer. This result follows from the fact that trade represents a relatively small fraction of GDP and, by the time prices are aggregated up to the consumer price level, the difference between the two pricing mechanisms has all but disappeared.

Our paper is related to recent quantitative studies of exchange rate behavior. Chari, Kehoe, and McGrattan (2002) assume that all goods are traded and explore the interaction between local currency pricing and monetary shocks in explaining real exchange rate behavior. Our study highlights the importance of nontradable goods in accounting for exchange rate behavior. Corsetti, Dedola, and Leduc (2004a) explore the role of (nontradable) distribution services in explaining the negative correlation between real exchange rates and relative consumption across countries, while Corsetti, Dedola, and Leduc (2004b) examine the behavior of pass-through in a model that includes distribution services.

The paper is organized as follows. In Section 2 we describe the model and in Section 3

[2]See, for instance, Engel (2002), Obstfeld (2001), and Obstfeld and Rogoff (2000).

we discuss the calibration. In Section 4 we present the results and perform some sensitivity analysis in Section 5. In Section 6 we discuss exchange rate pass-through and we conclude in Section 7.

2 The Model

The world economy consists of two countries, denominated home and foreign. Each country is populated by a continuum of identical households, firms, and a monetary authority. Households consume two types of final goods, a tradable good T and a nontradable good N. The production of nontradable goods requires capital and labor and the production of tradable consumption goods requires the use of home and foreign tradable inputs as well as nontradable goods. Therefore, consumer markets of tradable consumption goods are segmented and consumers are unable to arbitrage price differentials for these goods across countries.

Households own the capital stock and rent labor and capital services to firms. Households also hold domestic currency and trade a riskless bond denominated in home currency with foreign households. Each firm is a monopolistic supplier of a differentiated variety of a good and sets the price for the good it produces in a staggered fashion.

In what follows, we describe the home country economy. The foreign country economy is analogous. Asterisks denote foreign country variables.

2.1 Households

The representative consumer in the home country maximizes the expected value of lifetime utility, given by

$$U_0 = E_0 \sum_{t=0}^{\infty} \beta^t u \left(c_t, 1 - h_t, \frac{M_{t+1}}{P_t} \right), \tag{1}$$

where c_t denotes consumption of a composite good to be defined below, h_t denotes hours worked, M_{t+1}/P_t denotes real money balances held from period t to period $t+1$, and u represents the momentary utility function.

The composite good c_t is an aggregate of consumption of a tradable good $c_{T,t}$ and a nontradable good $c_{N,t}$, and is given by

$$c_t = \left(\omega_T^{\frac{1}{\gamma}} c_{T,t}^{\frac{\gamma-1}{\gamma}} + (1-\omega_T)^{\frac{1}{\gamma}} c_{N,t}^{\frac{\gamma-1}{\gamma}} \right)^{\frac{\gamma}{\gamma-1}}, \gamma > 0.$$

The parameter ω_T determines the agent's bias towards the tradable good and the elasticity of substitution between tradable and nontradable goods is given by γ.

Consumption of the tradable and nontradable good is a Dixit-Stiglitz aggregate of the quantity consumed of all the varieties of each good:

$$c_j = \left(\int_0^1 (c_j(i))^{\frac{\gamma_j - 1}{\gamma_j}} di \right)^{\frac{\gamma_j}{\gamma_j - 1}}, \quad j = T, N, \tag{2}$$

where γ_j is the elasticity of substitution between any two varieties of good j. Given home-currency prices of the individual varieties of tradable and nontradable goods, $P_{T,t}(i)$ and $P_{N,t}(i)$, the demand functions for each individual variety of tradable and nontradable goods, $c_{T,t}(i)$ and $c_{N,t}(i)$, and the consumption-based price of one unit of the tradable and nontradable good, $P_{T,t}$ and $P_{N,t}$, are obtained by solving a standard expenditure minimization problem subject to (2).

The representative consumer in the home country owns the capital stock k_t, holds domestic currency, and trades a riskless bond denominated in home-currency units with the foreign representative consumer. We denote by B_{t-1} the stock of bonds held by the household at the beginning of period t. These bonds pay the gross nominal interest rate R_{t-1}. There is a cost of holding bonds given by $\Phi_b(B_{t-1}/P_t)$, where $\Phi_b(\cdot)$ is a convex function.[3] The consumer rents labor services h_t and capital services k_t to domestic firms at rates r_t and w_t, respectively, both expressed in units of final goods.[4] Finally, households receive nominal dividends D_t from domestic firms and transfers T_t from the monetary authority.

The intertemporal budget constraint of the representative consumer, expressed in home-

[3]Costs of bond holdings guarantee that the equilibrium dynamics of our model are stationary. See Schmitt-Grohé and Uribe (2003) for a discussion and alternative approaches.

[4]We also allowed for variable capacity utilization of the capital stock. The results we emphasize in this paper are not affected by variable capital utilization. Results are available upon request.

currency units, is given by

$$P_t c_t + P_{T,t} i_t + M_{t+1} + B_t + P_t \Phi_b \left(\frac{B_{t-1}}{P_t} \right) \leq P_t \left(w_t h_t + r_t k_t \right) + R_{t-1} B_{t-1} + D_t + M_t + T_t. \quad (3)$$

Note that we assume that investment i_t is carried out in final tradable goods.[5] The law of motion for capital accumulation is

$$k_{t+1} = k_t(1-\delta) + k_t \Phi_k \left(\frac{i_t}{k_t} \right), \quad (4)$$

where δ is the depreciation rate of capital and $\Phi_k(\cdot)$ is a convex function representing capital adjustment costs.[6]

Households choose sequences of consumption, hours worked, investment, money holdings, debt holdings, and capital stock to maximize the expected discounted lifetime utility (1) subject to the sequence of budget constraints (3) and laws of motion of capital (4).

2.2 Production

There are three sectors of production: the nontraded goods sector, the intermediate traded goods sector, and the final tradable goods sector. In each sector firms produce a continuum of differentiated varieties.

2.2.1 Final Tradable Goods Sector

There is a continuum of firms in the final tradable goods sector, each producing a differentiated variety $y_T(i)$, $i \in [0,1]$. Each firm combines a composite of home and foreign tradable intermediate inputs X_T with a composite of nontradable goods X_N. The production function of each of these firms is

$$y_{T,t}(i) = \left(\omega^{\frac{1}{\rho}} X_{N,t}(i)^{\frac{\rho-1}{\rho}} + (1-\omega)^{\frac{1}{\rho}} X_{T,t}(i)^{\frac{\rho-1}{\rho}} \right)^{\frac{\rho}{\rho-1}}, \quad \rho > 0,$$

[5]This assumption is consistent with empirical evidence suggesting that investment has a substantial nontradable component and import content. See, for instance, Burstein, Neves, and Rebelo (2004).

[6]Capital adjustment costs are incorporated to reduce the response of investment to country-specific shocks. In their absence the model would imply excessive investment volatility. See, for instance, Baxter and Crucini (1995).

where ρ denotes the elasticity of substitution between $X_{T,t}(i)$ and $X_{N,t}(i)$ and ω is a weight. We interpret this sector as a retail sector. Thus, $X_{N,t}(i)$ can be interpreted as retail services used by firm i.[7]

For simplicity, we assume that the local nontradable good used for retail services $X_{N,t}$ is given by the same Dixit-Stiglitz aggregator (2) as the nontradable consumption good c_N. Thus, $P_{N,t}$ is the price of one unit of $X_{N,t}$. The composite of home and foreign intermediate tradable inputs $X_{T,t}$ is given by

$$X_{T,t} = \left[\omega_X^{\frac{1}{\xi}} X_{h,t}^{\frac{\xi-1}{\xi}} + (1-\omega_X)^{\frac{1}{\xi}} X_{f,t}^{\frac{\xi-1}{\xi}}\right]^{\frac{\xi}{\xi-1}}, \tag{5}$$

where $X_{h,t}$ and $X_{f,t}$ denote home and foreign intermediate traded goods, respectively. These goods X_h and X_f are each a Dixit-Stiglitz aggregate, as in (2), of all the varieties of each good produced in the home and foreign intermediate traded goods sector, $X_h(j)$ and $X_f(j)$, $j \in [0,1]$. Let the unit price (in home-currency units) of $X_{h,t}$ and $X_{f,t}$ be denoted by $P_{h,t}$ and $P_{f,t}$, respectively. Then, the price of one unit of the composite tradable good $X_{T,t}$ is given by

$$P_{X,t} = \left[\omega_X P_{h,t}^{1-\xi} + (1-\omega_X) P_{f,t}^{1-\xi}\right]^{\frac{1}{1-\xi}}. \tag{6}$$

Given these prices, the real marginal cost of production, common to all firms in this sector, is ψ_T,

$$\psi_{T,t} = \left[\omega \left(\frac{P_{X_N,t}}{P_t}\right)^{1-\rho} + (1-\omega)\left(\frac{P_{X_T,t}}{P_t}\right)^{1-\rho}\right]^{\frac{1}{1-\rho}}. \tag{7}$$

Firms in this sector set prices for J_T periods in a staggered way. That is, each period, a fraction $1/J_T$ of these firms optimally chooses prices that are set for J_T periods. The

[7] Note that we assume that the retail sector is a monopolistic competitive sector where each firm produces a differentiated good, by combining retail services X_T with a tradable composite X_N. With this assumption, the market structure of this sector mirrors that of the other sectors in our model. This assumption differs from that in other models that incorporate distribution/retail services, such as Burstein, Neves, and Rebelo (2003), Corsetti and Dedola (2005), and Corsetti, Dedola, and Leduc (2004a), which assume a perfectly competitive distribution sector where distribution costs are applied to each traded good separately.

problem of a firm i adjusting its price in period t is given by

$$\max_{P_{T,t}(0)} \sum_{i=0}^{J_T-1} E_t \left[\vartheta_{t+i|t} \left(P_{T,t}(0) - P_{t+i}\psi_{T,t+i} \right) y_{T,t+i}(i) \right],$$

where $y_{T,t+i}(i) = c_{T,t+i}(i) + i_{t+i}(i)$ represents the demand (for consumption and investment purposes) faced by this firm in period $t+i$. The term $\vartheta_{t+i|t}$ denotes the pricing kernel, used to value profits at date $t+i$ which are random as of t. In equilibrium $\vartheta_{t+i|t}$ is given by the consumer's intertemporal marginal rate of substitution in consumption, $\beta^i (u_{c,t+i}/u_{c,t}) P_t/P_{t+i}$.

2.2.2 Intermediate Traded Goods Sector

There is a continuum of firms in the intermediate traded goods sector, each producing a differentiated variety of the intermediate traded input, $X_h(i)$, $i \in [0,1]$, to be used by local and foreign firms in the retail sector. The production of each intermediate tradable input requires the use of capital and labor. The production function is $y_{h,t}(i) = z_{h,t} k_{h,t}(i)^{\alpha} l_{h,t}(i)^{1-\alpha}$. The term $z_{h,t}$ represents a productivity shock specific to this sector and $k_{h,t}$ and $l_{h,t}$ denote the use of capital and labor services by firm i. Each firm chooses one price, denominated in units of domestic currency, for the home and foreign markets. Thus, the law of one price holds for intermediate traded inputs.[8]

Like retailers, intermediate goods firms set prices in a staggered fashion. The problem of an intermediate goods firm in the traded sector setting its price in period t is described by

$$\max_{P_{h,t}(0)} \sum_{i=0}^{J_h-1} E_t \left[\vartheta_{t+i|t} \left(P_{h,t}(0) - P_{t+i}\psi_{h,t+i} \right) \left(X_{h,t+i}(i) + X^*_{h,t+i}(i) \right) \right], \tag{8}$$

where $X_{h,t+i}(i) + X^*_{h,t+i}(i)$ denotes total demand (from home and foreign markets) faced by this firm in period $t+i$. The term ψ_h denotes the real marginal cost of production (common

[8] Thus, in our benchmark model, the pass-through of exchange rate changes to import prices at the wholesale level is one. This pricing assumption makes our model consistent with the finding that the exchange rate pass-through is higher at the wholesale than at the retail level. Empirical evidence, however, suggests that exchange rate pass-through is lower than one even at the wholesale level (for instance, Goldberg and Knetter, 1997). Below we investigate the implications of alternative pricing assumptions for intermediate goods producers.

to all firm in this sector) and is given by

$$\psi_{h,t} = \frac{1}{z_{h,t}} \left(\frac{r_t}{\alpha}\right)^{\alpha} \left(\frac{w_t}{1-\alpha}\right)^{1-\alpha}. \tag{9}$$

2.2.3 Nontradable Goods Sector

This sector has a structure analogous to the intermediate traded sector. Each firm operates the production function $y_{N,t}(i) = z_{N,t} k_{N,t}(i)^{\alpha} l_{N,t}(i)^{1-\alpha}$, where all the variables have analogous interpretations. The price-setting problem for a firm in this sector is

$$\max_{P_{N,t}(0)} \sum_{i=0}^{J_N-1} E_t \left[\vartheta_{t+i|t} \left(P_{N,t}(0) - P_{t+i}\psi_{N,t+i}\right) y_{N,t+i}(i)\right],$$

where $y_{N,t+i}(i) = X_{N,t+i}(i) + c_{N,t+i}(i)$ denotes demand (from the retail sector and consumers) faced by this firm in period $t+i$. The real marginal cost of production in this sector is given by $\psi_{N,t} = \psi_{h,t} z_{h,t}/z_{N,t}$.

2.3 The Monetary Authority

The monetary authority issues domestic currency. Additions to the money stock are distributed to consumers through lump-sum transfers $T_t = M_t^s - M_{t-1}^s$.

The monetary authority is assumed to follow an interest rate rule similar to those studied in the literature. In particular, the interest rate is given by

$$R_t = \rho_R R_{t-1} + (1-\rho_R)\left[\overline{R} + \rho_{R,\pi}\left(E_t \pi_{t+1} - \overline{\pi}\right) + \rho_{R,y} \ln\left(y_t/\overline{y}\right)\right], \tag{10}$$

where π_t denotes CPI-inflation, y_t denotes real GDP, and barred variables represent their target value.

2.4 Market Clearing Conditions and Model Solution

We close the model by imposing market clearing conditions for labor, capital, and bonds,

$$\begin{aligned} h_t &= \sum_{i=0}^{J_h-1} l_{h,t}(i) + \sum_{i=0}^{J_N-1} l_{N,t}(i), \\ k_t &= \sum_{i=0}^{J_h-1} k_{h,t}(i) + \sum_{i=0}^{J_N-1} k_{N,t}(i), \\ 0 &= B_t + B_t^*. \end{aligned}$$

We focus on the symmetric and stationary equilibrium of the model. We solve the model by linearizing the equations characterizing equilibrium around the steady-state and solving numerically the resulting system of linear difference equations.

We now define some variables of interest. The real exchange rate q, defined as the relative price of the reference basket of goods across countries, is given by $q = eP^*/P$. The terms of trade τ represent the relative price of imports in terms of exports in the home country and are given by $\tau = P_f/(eP_h^*)$. Nominal GDP in the home country is given by $Y = Pc + P_T i + NX$, where $NX = eP_h^* X_h^* - P_f X_f$ represents nominal net exports. We obtain real GDP by constructing a chain-weighted index as in the National Income and Product Accounts.

3 Calibration

In this section we report the parameter values used in solving the model. Our benchmark calibration assumes that the world economy is symmetric so that the two countries share the same structure and parameter values. The model is calibrated largely using US data as well as productivity data from the OECD Stan data base. We assume that a period in our model corresponds to one quarter. Our benchmark calibration is summarized in Table 1.

3.1 Preferences and Production

We assume a momentary utility function of the form

$$U\left(c, l, \frac{M}{P}\right) = \frac{1}{1-\sigma}\left\{\left(ac^{\eta} + (1-a)\left(\frac{M}{P}\right)^{\eta}\right)^{\frac{1-\sigma}{\eta}} \exp\left\{-v(h)(1-\sigma)\right\} - 1\right\}. \tag{11}$$

The discount factor β is set to 0.99, implying a 4% annual real rate in the stationary economy. We set the curvature parameter σ equal to two.

The parameters a and η are obtained from estimating the money demand equation implied by the first-order condition for bond and money holdings. Using the utility function defined above, this equation can be written as

$$\log\frac{M_t}{P_t} = \frac{1}{\eta-1}\log\frac{a}{1-a} + \log c_t + \frac{1}{\eta-1}\log\frac{R_t-1}{R_t}. \tag{12}$$

We use data on $M1$, the three-month interest rate on T-bills, consumption of non-durables and services, and the price index is the deflator on personal consumption expenditures. The sample period is 1959:1-2004:3. The parameter estimation is carried out in two steps. Because real $M1$ is non-stationary and not co-integrated with consumption, equation (12) is first differenced. The coefficient estimate on consumption is 0.975 and is not statistically different from one, so the assumption of a unitary consumption elasticity implied by the utility function is consistent with the data. The coefficient on the interest rate term is -0.021, and we calibrate η to be -32, which implies an interest elasticity of -0.03. Next, we form a residual $u_t = \log(M_t/P_t) - \log c_t - \frac{1}{\eta-1}\log\frac{R_t-1}{R_t}$. This residual is a random walk with drift and we use a Kalman filter to estimate the drift term, which is the constant in equation (12). The resulting estimate of a is very close to one and we set a equal to 0.99.[9] Therefore, our calibration is close to imposing separability between consumption and real money balances.

[9] The estimation procedure neglects sampling error, because in the second stage we are treating η as a parameter rather than as an estimate.

Labor disutility is assumed to take the form

$$v(h) = \frac{\psi_0}{1+\psi_1} h^{1+\psi_1}.$$

The parameters ψ_0 and ψ_1 are set to 3.467 and 0.146, respectively, so that the fraction of working time in steady-state is 0.25 and the elasticity of labor supply, with marginal utility of consumption held constant, is 2. This elasticity is consistent with estimates in Mulligan (1998) and Solon, Barsky, and Parker (1994).

The elasticity of substitution between tradable and nontradable goods in consumption, γ, is set to 0.74 following Mendoza's (1995) estimate for a sample of industrialized countries. We assume that nontradable inputs (retail services) and tradable inputs exhibit very low substitutability in the production of final tradable goods and are used in fixed proportions. We thus set the elasticity of substitution ρ to 0.001. There is considerable uncertainty regarding estimates of the elasticity of substitution between domestic and imported goods, ξ. In addition, this parameter has been shown to play a crucial role in key business cycle properties of two-country models.[10] A reference estimate of this elasticity for the U.S. has been 1.5 from Whalley (1985). Hooper, Johnson, and Marquez (1998) estimate import and export price elasticities for G-7 countries and report elasticities for the U.S. between 0.3 and 1.5. We set this elasticity to the mid point in this range (0.85) and perform sensitivity analysis.

We choose the weights on consumption of tradable goods ω_T, on nontradable retail services ω and on domestic traded goods ω_X to simultaneously match, given all other parameter choices, the share of consumption of nontradable goods in GDP, the share of retail services in GDP, and the average share of exports plus imports in GDP. Over the period 1973-2004, these shares in the U.S. averaged 0.44, 0.19, and 0.13, respectively. For our benchmark model, we obtained $\omega_T = 0.44$, $\omega = 0.38$, and $\omega_X = 0.59$. Given these parameter choices, the model implies a share of nontradable consumption in total consumption of 0.55, which is consistent with the data.

We set the elasticity of substitution between varieties of a given good, γ_j, equal to 10,

[10] See, for example, Corsetti, Dedola, and Leduc (2004a) and Heathcote and Perri (2002).

for all goods $j = T, N, h$. As usual, this elasticity is related to the markup chosen when firms adjust their prices, which is $\gamma_j / (\gamma_j - 1)$. Our choice for γ_j implies a markup of 1.11, which is consistent with the empirical work of Basu and Fernald (1997). In our benchmark calibration, we assume that all firms set prices for 4 quarters ($J_j = 4$).

Regarding production, we take the standard value of $\alpha = 1/3$, implying that one-third of payments to factors of production goes to capital services.

3.2 Monetary Policy Rule

The parameters of the nominal interest rate rule are taken from the estimates in Clarida, Galí, and Gertler (1998) for the US. We set $\rho_R = 0.9$, $\alpha_{p,R} = 1.8$, and $\alpha_{y,R} = 0.07$. The target values for R, π, and y are their steady-state values, and we have assume a steady-state inflation rate of 2 percent per year.

3.3 Capital Adjustment and Bond Holding Costs

We model capital adjustment costs as an increasing convex function of the investment to capital stock ratio. Specifically, $\Phi_k(i/k) = \phi_0 + \phi_1(i/k)^{\phi_2}$. We parameterize this function so that $\Phi_k(\delta) = \delta$, $\Phi_k'(\delta) = 1$, and the volatility of HP-filtered consumption relative to that of HP-filtered private GDP is approximately 0.64.

The bond holdings cost function is $\Phi_b\left(B_t/P_t\right) = \theta_b/2\left(B_t/P_t\right)^2$. The parameter θ_b is set to 0.001, the lowest value that guarantees that the solution of the model is stationary, without affecting the short-run properties of the model.

3.4 Productivity Shocks

The technology shocks are assumed to follow independent $AR(1)$ processes $z_{i,t}^k = Az_{i,t-1}^k + \varepsilon_{i,t}^k$, where $i = \{U.S., ROW\}$ and $k = \{mf, sv\}$; ROW stands for rest of world, mf for manufacturing and sv for services. $\varepsilon_{i,}^k$ represents the innovation to z_i^k and has standard deviation σ_i^k. The data are taken from the OECD STAN data set on total factor productivity (TFP) for manufacturing and for wholesale and retail services. The data is annual and runs from 1971-1993 making for a very short sample in which to infer the time series characteristics of these measures. We cannot reject a unit root for any of the series, which is consistent with other data series on productivity in manufacturing, namely that constructed by the BLS or Basu, Fernald, and Kimball (2004).

The shortness of the time series on TFP prevents us from estimating any richer characterization of TFP with any precision.[11] In looking at the univariate autoregressive estimates we found coefficients ranging from 0.9 for U.S. manufacturing to 1.05 for rest of world services. Therefore, we use as a benchmark a stationary, but highly persistent processes for each of the technology shocks. Based on these simple regressions, we set $A = 0.98$ and we set the standard deviations of the TFP on manufacturing and services to 0.006 and 0.003 respectively.

4 Findings

In this section we assess the role of nontradable goods in our model. We report HP-filtered population moments for our model under the benchmark and alternative parameterizations in Table 2.[12] We find that the presence of either nontradable consumption goods or retail services raises the volatility of real and nominal exchange rates relative to GDP by a factor of about 1.5. In addition the presence of nontradable goods also lowers the correlation between exchange rates and other macro variables. Therefore, nontradable goods bring a standard two-country open economy model closer to the data. Finally, in the presence of nontradable goods, the asset structure of the model (and whether agents have access to a complete set of state-contingent assets or not) matters for the adjustment to country-specific shocks. This result is in sharp contrast with many other two-country models, where agents are able to optimally share risk across states and dates with one discount bond only.

Table 1: Calibration

Preferences	
Coefficient of risk aversion (σ)	2
Elasticity of labor supply	2
Time spent working	0.25
Interest elasticity of money demand ($1/(\nu - 1)$)	-0.03
Weight on consumption (a)	0.99
Aggregates	
Elast. of substitution C_N and C_T (γ)	0.74
Elast. of substitution X and Ω (ρ)	0.001
Elast. of substitution X_h and X_f (ξ)	0.85
Elast. of substitution individual varieties	10
Share of imports in GDP	0.13
Share of retail services in GDP	0.19
Share of C_N in GDP	0.44
Production and Adjustment Functions	
Capital share (α)	1/3
Price stickiness (J)	4
Depreciation rate (δ)	0.025
Relative volatility of investment	2.5
Bond Holdings (b)	0.001
Monetary Policy	
Coeff. on lagged interest rate (ρ_R)	0.9
Coeff. on expected inflation ($\rho_{p,R}$)	1.8
Coeff. on output ($\rho_{y,R}$)	0.07
Productivity Shocks	
Autocorrelation coeff. (A)	0.98
Std. dev. of innovations to $z_T \& z_N$	0.006 & 0.003

4.1 The Benchmark Economy

The benchmark model implies that nominal and real exchange rates are about 1.6 times as volatile as real GDP. In the data, dollar nominal and real exchange rates are about 4.5 times as volatile as real GDP.[13] The volatility of nominal and real exchange rates in our model is accounted mostly by productivity shocks to the nontraded goods sector. Shocks to

[11] We estimated a VAR to investigate the relationship across the four TFP series. It was hard to make sense of the results. In this regard our results are similar to those of Baxter and Farr (2001) who analyze the relationship between total factor productivity in manufacturing between the U.S. and Canada.

[12] We thank Robert G. King for providing the algorithms that compute population moments.

[13] We report data values from Chari, Kehoe, and McGrattan (2002).

Table 2: Model results

Statistic	Benchmark Economy	No Retail	No C_{NT}	No NT	Complete Markets
Stand. Dev. Relative to GDP					
Consumption	0.64	0.64	0.64	0.64	0.64
Investment	2.41	2.01	1.93	2.03	2.58
Employment	1.10	0.79	0.27	0.24	1.23
Nominal E.R.	1.54	1.16	1.11	1.22	1.12
Real E.R.	1.50	1.25	1.08	1.17	1.05
Terms of trade	2.27	2.49	1.79	1.58	1.70
Net Exports	0.31	0.15	0.06	0.10	0.38
Autocorrelations					
GDP	0.66	0.85	0.81	0.80	0.60
Nominal E.R.	0.80	0.79	0.80	0.80	0.80
Real E.R.	0.80	0.81	0.80	0.80	0.79
Terms of trade	0.88	0.90	0.88	0.86	0.88
Net Exports	0.48	0.63	0.70	0.69	0.49
Cross-correlations					
Between nominal and real E.R.	0.99	0.99	0.99	0.99	0.98
Between real exchange rates and					
GDP	0.47	0.57	0.62	0.64	0.40
Terms of trade	0.62	0.76	0.96	0.99	0.51
Relative consumptions	0.83	0.80	0.97	0.99	0.87
Between foreign and domestic					
GDP	0.36	0.15	0.16	0.15	0.49
Consumption	0.40	0.38	0.60	0.52	0.42
Investment	0.44	0.56	0.41	0.31	0.46
Employment	0.52	0.10	-0.06	0.52	0.66

productivity in the traded goods sector imply minimal responses of exchange rates in the benchmark model. As in the data, exchange rates in our model are much more volatile than the price ratio P^*/P (about 7 times) and are highly correlated with each other (0.99).

In general, movements in the real exchange rate can be decomposed into deviations from the law of one price for traded goods and movements in the relative prices of nontraded to traded goods across countries.[14] Let q_T denote the real exchange rate for traded goods, defined as $q_T = eP_T^*/P_T$. Then, the real exchange rate can be written as $q = q_T p$, where p is a

[14]See, for example, Engel (1999).

function of the relative prices of nontraded to traded goods in the two countries.[15] Empirical evidence (e.g., Engel, 1999, Obstfeld, 2001) suggests that the all-goods q and traded-only q_T real exchange rates are highly correlated and that the variability of the real exchange rate for all goods, q, is mostly accounted for by variability in q_T, when the price of traded goods is measured using retail prices. In our model, the correlation coefficient between q and q_T is 0.95 and the standard deviation of q_T is about 2.5 times that of p. That is, in our model, movements in the relative price of nontraded to traded goods play a minimal role in real exchange rate movements. As we shall see, this finding does not imply, however, that nontraded goods do not play an important role in the behavior of exchange rates in our model.

Nominal and real exchange rates are more persistent than output and consumption (0.80 versus 0.66 and 0.63), but not as persistent as in the data (0.86 and 0.83). The cross-correlation between exchange rates and the terms of trade is positive and consistent with the data (0.62). The cross-correlation between the real exchange rate and the ratio of consumption across countries, however, is substantially higher than in the data (0.83 versus -0.35).

With respect to consumption, investment, and employment the model implies volatilities relative to real output that are broadly consistent with the data. These variables, however, display less persistence than in the data. The model implies a cross-correlation of home and foreign consumption similar to that found in the data (0.40 versus 0.38). The cross-correlation of home and foreign output is similar to that of home and foreign consumption but lower than in the data (0.36 versus 0.60). The cross-correlations of home and foreign investment and employment are broadly consistent with the data. It should be noted that in our benchmark calibration all exogenous shocks are independent across countries and thus these positive cross-correlations reflect the endogenous transmission mechanism of shocks across countries in our model.

[15] In our model $p = \left(\frac{\omega_T + (1-\omega_T)(P_N^*/P_T^*)^{1-\gamma}}{\omega_T + (1-\omega_T)(P_N/P_T)^{1-\gamma}}\right)^{\frac{1}{1-\gamma}}$.

4.2 The Role of Nontradable Goods

Nontradable goods enter our model in two ways. First, households derive utility from the consumption of nontradable goods. Second, our model features a monopolistically competitive retail sector in which firms combine tradable inputs with (nontradable) retail services to produce differentiated final retail goods. In Table 2 we report statistics for our model when we eliminate retail services, nontradable consumption goods, or both. We eliminate retail services by setting the share of retail services in GDP to 0.001, while keeping the shares of imports and consumption of nontradable goods in GDP as in the benchmark model. We eliminate nontradable consumption goods by setting the share of final nontradable consumption goods in GDP to 0.001, while maintaining the shares of imports and retail services in GDP unchanged.

The presence of nontradable goods (as nontradable consumption goods and retail services) has important implications for both exchange rate volatility and for cross-correlations of exchange rates and terms of trade with other variables in the model. Nontradable retail services or consumption goods increase the volatility of the nominal exchange rate relative to the volatility of real GDP by a factor of 1.5. The effects of nontradable goods on the real exchange rate are similar since exchange rates are almost perfectly correlated in all alternative versions of the model. In addition, the correlation between the real exchange rate and real GDP, the terms of trade, and the ratio of consumption across countries rises as we eliminate nontradable goods. Similarly, the cross-correlation of the terms of trade with the ratio of consumptions across countries and GDP also rises when we eliminate nontradable goods.

The presence of nontradable goods matters for the adjustment to shocks to productivity in both the traded and nontraded goods sectors. We now focus on the role of these goods in the adjustment following shocks to productivity in the nontradable goods sector.

Shocks to Nontraded Goods Productivity The response of selected variables to a positive shock to productivity in the nontradable goods sector is depicted in Figure 2. In response to this shock, the price of nontraded goods falls. Absent a response of monetary policy, the price level also falls. When the monetary authority follows the interest rate rule in (10), the money stock expands, largely maintaining the price level constant in response to this shock.

Following a persistent shock to productivity in the nontraded goods sector (and the associated response of monetary policy) real GDP, consumption, and investment in the home country increase on impact and later fall gradually to their deterministic steady-state levels. Given the rise in the relative price of tradable goods, the increase in consumption is associated with a substitution towards nontradable goods and away from tradable goods. Following this shock, home consumers want to invest more, in order to increase the capital stock in the nontraded sector. Investment goods, however, require the use of traded goods and nontradable goods in fixed proportions while the country is more productive at producing nontradable goods only. Therefore, the country runs a current account deficit (and becomes a net debtor) in response to this shock.

The nominal exchange rate depreciates following the positive shock to productivity in the nontraded goods sector. This nominal depreciation is associated with an increase of the domestic terms of trade τ (defined as the relative price of domestic imports in terms of domestic exports). Absent a terms of trade movement, the demand for home and foreign inputs would increase proportionately to satisfy higher domestic investment and consumption of tradable goods. The nominal exchange rate (and terms of trade) depreciation makes domestic firms substitute domestic-produced inputs for foreign-produced goods, dampening the demand for foreign inputs and the required adjustment of foreign labor hours. The real exchange rate also depreciates following this shock. It moves closely together with the nominal exchange rate since monetary policy ensures that price levels remain relatively constant. The presence of nontraded goods (as retail services or nontradable consumption goods) increases the share of output that benefits from a positive shock to productivity in this sector and thus magnifies the response of exchange rates relative to the response of output.

The presence of retail services and nontradable consumption goods magnifies the response of exchange rates relative to output following shocks to productivity in the nontradable goods sector while leaving the correlations of exchange rates with other variables largely unchanged. In response to shocks to productivity in the traded goods sector, however, the presence of nontradable goods affects both the magnitude of the response of exchange rates relative to output and the correlations of exchange rates with other variables in the model.

Shocks to Traded Goods Productivity In response to a positive shock in the home country, the price of domestically-produced intermediate inputs falls while the price of nontradable goods remains largely unchanged. Therefore, the aggregate price level falls slightly. The impulse response functions for selected variables are depicted in Figure 1.

Note that in the benchmark model, agents derive utility from the consumption of nontradable goods and traded goods. Traded goods require the use of nontradable goods and traded inputs in fixed proportions. Therefore, a persistent positive shock to productivity in the traded sector affects only the production of domestic traded inputs used in the production of consumption traded goods and this shock has a relatively small effect. Consumption, investment, and real GDP fall slightly on impact, but rise as traded goods firms lower their prices. Since the price of home intermediate inputs falls relative to both foreign intermediate inputs and nontradable goods, the home country's demand for intermediate inputs increases and firms in the retail sector substitute towards local inputs and away from imported inputs. Shocks to productivity in the traded goods sector imply negligible movements in exchange rates in our benchmark model.

In the absence of retail services or nontraded consumption goods, the share of the traded sector in output increases and the effects of shocks to productivity in this sector increase as well. In particular, in the absence of nontraded goods, these shocks imply a bigger decrease of the aggregate price level (absent a response of monetary policy) and thus trigger a bigger increase in the money stock when the monetary authority follows (10). It follows that the nominal exchange rate depreciates more in the absence of nontraded goods and the role of these shocks in accounting for exchange rate volatility increases in the absence of nontraded goods. Note that as the relative importance of traded goods in the economy increases, the response of all variables (and, in particular, exchange rates) to productivity shocks increases. Therefore, the commovement between exchange rates and other variables in the model also increases in the absence of nontradable goods.

4.3 The Role of Asset Markets

In our model, the assets available to share risk matter for the adjustment to country-specific shocks, specially those to productivity in the nontraded goods sector. As results in Table 2 show, nominal and real exchange rates are less volatile relative to real GDP with complete markets than when agents are restricted to trading a riskless bond. Complete asset markets also increase the relative volatility of investment and employment relative to the benchmark model and it raises the cross-correlation between home and foreign output and employment. Complete asset markets increase slightly the cross-correlation between the real exchange rate and the ratio of consumption across countries relative to the benchmark model. This correlation, however, is still lower than under incomplete markets when nontradable goods are absent in our model.

When agents have access to a complete set of state-contingent nominal assets, the efficiency conditions for bond holdings imply that

$$\frac{u_{c,t+1}}{u_{c,t}}\frac{P_t}{P_{t+1}} = \frac{u^*_{c,t+1}}{u^*_{c,t}}\frac{e_t P^*_t}{e_{t+1}P^*_{t+1}}, \tag{13}$$

where u_c denotes the marginal utility of consumption. This expression can be further simplified to

$$\frac{u^*_{c,t}}{u_{c,t}} = \kappa_0 \frac{e_t P^*_t}{P_t},$$

where κ_0 is a constant that depends on the distribution of wealth across countries in period 0.[16] This equation shows that, under complete asset markets, optimal risk sharing across countries implies that the marginal consumption value of a unit of currency is equal across countries in all states of nature.

When agents are restricted to trade a riskless bond, as in our bechmark model, equation (13) holds only in expectation. Typically, in two-country models, the equilibrium allocation with incomplete asset markets is close to the allocation with complete asset markets. That is, agents are typically able to optimally diversify the country-specific risk they face with one riskless bond only.[17] In our model, however, agents cannot optimally diversify the country-

[16] See, for instance, Chari, Kehoe, and McGrattan (2002).

[17] See, for example, Baxter and Crucini (1995), Chari, Kehoe, and McGrattan (2002), and Duarte and

specific risk they face with a riskless bond only.

The major difference between the two risk sharing environments occurs in response to shocks to productivity in the nontraded goods sector. In response to a positive and persistent productivity shock to the nontraded goods sector in the home country, the home agent wishes to consume and invest more. Since the country is more productive in nontraded goods only, the home agent borrows from the foreign agent. The nominal exchange rate and the terms of trade of the home country depreciate, ensuring a substitution effect towards inputs produced in the home country and away from inputs produced in the foreign country.

The optimal risk sharing contract between home and foreign agents, however, is such that in response to a shock to productivity in the nontraded goods sector of the home country, the foreign agent works more (and substitutes hours towards the traded sector and away from the nontraded sector) and consumes less. That is, relative to the incomplete markets case, the foreign agent produces more traded goods and a smaller exchange rate depreciation is needed to equate the demand and supply of foreign traded goods.

5 Alternative Price Setting Mechanisms

In this section we examine how our model economy behaves under local currency pricing (LCP) when producers are able to discriminate across markets and set prices for their good in the local currency as compared to our benchmark pricing mechanism of producer currency pricing (PCP). With regard to the broader implications of pricing, we find that our model economies behave quite similarly whether producers discriminate across markets and set their prices in the currency of the buyer or whether they set a common price for both markets in the currency of the seller. One aspect that differs across the two specifications is the correlation between the terms of trade and exchange rates. They are lower under LCP, but the difference is not as striking as one might expect.

Stockman (2005).

5.1 Price Setting under Alternative Pricing Mechanisms

Our benchmark price-setting specification is producer currency pricing. Under this arrangement the behavior of the (log-linearized) price of the home intermediate traded good behaves according to

$$\widetilde{p}_{h,t}(0) = E_t(\sum_{j=0}^{J_h-1} \rho_j \widetilde{\psi}_{h,t+j} + \sum_{j=0}^{J_h-1} \rho_j \widetilde{P}_{t+j}), \tag{14}$$

where a "~" over a variable indicates the log-linearization of the variable around its steady state value, E_t is the conditional expectation operator where expectations are conditioned on all information as of time t, and ρ_j is a function of β.[18] Equation (14) is derived from the first-order condition of problem (8) in section 2, and we have linearized around a zero inflation steady state. Notice that variables that scale the level of demand do not enter the equation, because to a first-order approximation around the optimal price, they influence marginal cost and marginal revenue to the same extent.

Under local currency pricing, producers of intermediate traded goods are able to discriminate across markets and separately solve for the optimal price in the currency of the buyer in each market. The log-linearized pricing equations for the price of the home traded good at home and abroad are given by,

$$\widetilde{p}_{h,t}(0) = E_t(\sum_{j=0}^{J_h-1} \rho_j \widetilde{\psi}_{h,t+j} + \sum_{j=0}^{J_h-1} \rho_j \widetilde{P}_{t+j}), \tag{15}$$

and

$$\widetilde{p}^{*}_{h,t}(0) = E_t(\sum_{j=0}^{J_h-1} \rho_j \widetilde{\psi}_{h,t+j} + \sum_{j=0}^{J_h-1} \rho_j (\widetilde{P}_{t+j} - \widetilde{e}_{t+j})),$$

respectively. Observe that the pricing equation for the home traded good sold domestically is the same under both mechanisms (equations 14 and 15). Furthermore, note that under LCP, the law of one price holds for newly priced goods (i.e., $\widetilde{p}^{*}_{h,t}(0) = \widetilde{p}_{h,t}(0) - \widetilde{e}_t$) for random walk behavior of the exchange rate. Since the behavior of the exchange rate is close to a random walk in our model, the price of newly priced goods is almost identical across countries

[18] In particular, $\rho_j = \beta^j / \left(\sum_{j=0}^{J_h-1} \beta^j\right)$. For β close to one, $\rho_j \approx 1/J_h$.

regardless of the price setting mechanism. Therefore, differences across the two price setting mechanisms can only come from differences in the relative price across countries of prices that are preset. However, as additional vintages of firms reset their prices, the distinction between the two price setting mechanisms disappears. Thus, any potential differences will be short lived, and because the differences are transitory they should not affect variables like investment or consumption to any great degree.

5.2 Impulse Responses and Model Moments

To examine the effect of different pricing mechanisms on the behavior of our model economy, we first look at impulse response functions to the various shocks. These are displayed in Figures 3 and 4. Because our model is symmetric, we concentrate on the behavior of the home country to domestic disturbances. The first thing to notice is that in response to each of the shocks, the behavior of the nominal exchange rate, output, and the price level is not influenced substantially by the different pricing arrangements. One underlying reason is that trade is a small portion of the economy: Although there are differences in the response of import prices, this difference diminishes as prices are aggregated up to the consumer price level. In fact, there is not much difference even in the behavior of the price of the intermediate home traded good under the different pricing systems. A second reason that the two pricing mechanisms lead to similar behavior is that, as discussed before, price setters respond much the same under LCP as they do under PCP. Thus, any difference between the two mechanisms follows from the existence of preset prices. However, as successive vintages of firms reset their prices the behavior of the price of imports across the different pricing mechanisms converges. A third factor contributing to the similar behavior under the two pricing mechanisms is that, with respect to the traded goods technology shock, which is the largest variance shock in the model, the nominal exchange rate does not respond very much. As a result, under LCP, unanticipated shocks to productivity in the traded goods sector do not generate large deviations from the law of one price even for goods whose price is preset. Therefore, there is not much scope for the pricing systems to influence the economy as a whole.

Regarding the relationship between import prices and the nominal exchange rate, it is only with respect to the technology shocks to non-traded goods that the price of imports responds more strongly on impact under PCP than LCP. Thus, from the impulse response functions it would appear that the nominal exchange rate and the price of imports would be slightly more positively correlated under PCP, and this is indeed the case (see Table 3). After HP filtering, the correlation coefficient between these two variables is 0.71 under PCP and 0.48 under LCP.

The most noticeable difference across pricing mechanisms is the behavior of the terms of trade in response to the non-traded goods technology shock. An increase in technology in the non-tradable goods sector leads to a substantial depreciation of the nominal exchange rate. With producer currency pricing, the price of the home import good rises by more than the exchange rate, because preset prices move one for one with the exchange rate and price setters in the foreign country raise their price in response to the increase in domestic demand. The price of home exports rises due to higher domestic wages but less so than the exchange rate. As a result the terms of trade depreciate. Under LCP, preset prices are not affected by the exchange rate, and on impact the aggregate price indices for traded goods do not respond as much as the nominal exchange rate. As a result, the movement in the nominal exchange rate dominates the movement in the terms of trade. Thus, on impact, the depreciation of the nominal exchange rate leads to an appreciation of the terms of trade. However, as additional vintages of firms adjust their prices, the pricing effect dominates and the terms of trade eventually depreciates. Therefore, these impulse response functions suggest that the correlation between the exchange rate and the terms of trade would be lower under LCP. This is indeed the case. Under LCP the correlation is 0.11, while it is 0.51 under PCP.

In comparing model moments, we look at population moments of HP filtered model data. The relative volatilities of various variables are not affected much by the pricing mechanism. For example, under PCP the relative standard deviations of consumption, investment, the nominal exchange rate, and the terms of trade are 0.64, 2.41, 1.54, and 2.27 respectively, while under LCP they are 0.64, 2.60, 1.30, and 2.20. Similarly, the model also implies similar persistence across pricing mechanisms. In particular, the autocorrelation coefficients for output, the nominal exchange rate, the terms of trade, and the price of domestic imports are 0.66, 0.80, 0.87, and 0.85 under PCP, while they are 0.65, 0.79, 0.88, and 0.93. It is only the greater persistence of import prices under LCP that slightly distinguishes the two models.

In Table 3 we report the correlation coefficients between output, consumption, exchange rates, terms of trade, price of imports and net exports under the two alternative systems. The correlations for PCP are in the upper triangular part of the table and those for LCP are in the lower part.

Table 3: Model Correlations

	y	c	e	q	τ	P_f	NX
y	–	0.95	0.43	0.47	0.48	0.38	-0.43
c	0.95	–	0.45	0.45	0.27	0.33	-0.43
e	0.37	0.41	–	0.99	0.51	0.71	-0.52
q	0.40	0.41	0.98	–	0.63	0.77	-0.52
τ	0.27	0.10	0.11	0.26	–	0.80	-0.44
P_f	0.25	0.23	0.48	0.58	0.73	–	-0.47
NX	-0.37	-0.41	-0.49	-0.49	-0.17	-0.31	–

There is one major difference among the correlations across the two pricing systems: The terms of trade is more highly correlated with exchange rates under producer currency pricing. In the model with PCP, the correlation coefficient between the terms of trade and the nominal exchange rate is 0.51 and with LCP it is 0.11. For data on Canada, the UK, Germany, Italy, France, and the U.S. the comparable correlation ranges from 0.34 for Canada to 0.70 for Germany and averages 0.47.[19] Thus, the PCP model is more in line with the data regarding the correlations between the terms of trade and exchange rates. This finding is consistent with the discussion in Obstfeld (2001).

6 Sensitivity Analysis

In this section we perform sensitivity analysis along three dimensions. First, we increase the share of consumption of nontradable goods in GDP to levels consistent with recent

[19]The data used is the relative price of imports to exports and the trade-weighted nominal exchange rate, obtained from the Bank of England's web site.

data. Second, we investigate the importance of the elasticity of substitution between local and imported goods. Third, we examine the effects of positive cross-country correlation in innovations to technology in the traded goods sector. Our analysis focuses on the effects that alternative calibrations have on the role of nontradable goods in our model.

The share of consumption of nontradable goods in GDP in the U.S. has increased over our sample period. While over the entire period the average is 0.44, it averaged 0.51 from 2001 to 2004. Increasing the share of consumption of non-tradable goods in GDP in our model from 0.44 to 0.51, does not impart any additional effects in terms of relative exchange rate volatility. In this case the relative standard deviation of the nominal exchange rate increases to 1.53. Thus, it appears that incorporating non-tradable goods is helpful, but that further increasing their share beyond the benchmark has only a marginal effect. Also, while the presence of nontradable goods in the benchmark model lowers the correlation of relative consumption and the real exchange rate from 0.99 to 0.82, there is no additional improvement when the share of non-tradable goods in consumption is increased.

The elasticity of substitution between local and imported goods is an important parameter in the model. This feature has been emphasized extensively by Corsetti, Dedola, and Leduc (2004a) and Benigno (2004). In Table 4 we report the relative volatility of the nominal exchange rate and the correlation coefficient between the real exchange rate and the ratio of consumptions across countries for different values of the elasticity of substitution ξ and alternative model specifications. Consistent with the findings in the papers above, we find that for our benchmark calibration (columns 2 and 3 in Table 4) lowering this elasticity has dramatic effects: The relative volatility of the exchange rate increases substantially and the correlation between relative consumptions and the real exchange rate declines, eventually becoming negative as in the data.

The behavior of relative consumptions and exchange rates that leads to this negative correlation are those described in the relatively high elasticity calibration of Corsetti et al., namely that in response to a home traded-goods technology shock foreign consumption increases relative to domestic consumption, while the nominal exchange rate depreciates. The reason that consumption behaves in this way is due to the low substitutability of intermediate traded goods in the production of the traded goods aggregate. Because of this low

Table 4: Elasticity of Substitution

ξ	Benchmark $sd(e)/sd(y)$	Benchmark $\rho(\frac{C}{C^*}, q)$	no z_N shocks $sd(e)/sd(y)$	no z_N shocks $\rho(\frac{C}{C^*}, q)$	no NT $sd(e)/sd(y)$	no NT $\rho(\frac{C}{C^*}, q)$
0.45	3.27	-0.12	3.18	-0.95	3.14	-0.83
0.55	2.49	0.33	2.92	-0.81	2.86	0.73
0.65	1.98	0.60	1.87	-0.63	1.98	0.96
0.75	1.65	0.75	0.95	-0.40	1.52	0.99
0.85	1.54	0.83	0.33	-0.13	1.22	0.99
0.95	1.37	0.86	0.17	0.23	1.04	0.99
1.05	1.32	0.87	0.49	0.61	0.89	0.99
1.15	1.27	0.86	0.74	0.23	0.79	0.99
1.25	1.25	0.84	0.94	0.11	0.70	0.99

substitutability, the demand for foreign traded goods increases dramatically. In order to induce production of foreign traded goods, their price must rise significantly. The home traded becomes inexpensive relative to foreign traded goods, and foreign demand for the domestically produced traded good increases. The foreign country produces more traded goods than the home country and foreign consumption rises relative to that of the home country. Further, the large decline in the price of the home tradeable relative to the price of the foreign tradeable implies that the terms of trade and the real exchange both depreciate. Thus, the negative correlation induced by the low degree of substitutability occurs because foreign consumption rises relative to domestic consumption in the presence of a depreciating exchange rate.

The relation between non-tradable goods and the elasticity of substitution between intermediate traded goods on these two model moments is reported in the last four columns of Table 4. There are two channels in which non-traded goods can affect these moments in our model: shocks to non-tradable goods productivity and non-tradable goods in production and consumption. Shocks to non-tradable goods productivity have a profound effect on these moments. At elasticities of 0.75 and higher the relative volatility of the exchange rate is drastically reduced when there is no shock to non-tradable goods productivity. Another consequence of removing shocks to non-tradable goods productivity is that the model generates substantially lower correlations between relative consumptions and real exchange rates.

In fact, the correlation is negative for elasticities around 0.85 and lower.[20]

Comparing columns four and five with six and seven in Table 4, the presence of non-tradable goods also has a substantial effect on the correlations between relative consumptions and the real exchange rate, but not a large effect on relative volatilities. Without non-tradable goods in either consumption or production, the correlation coefficient is substantially larger. With regard to relative volatilities, at elasticities near one the presence of non-traded goods actually dampens the relative volatility of the nominal exchange rate.

Lastly, we looked at the effect of correlated innovations to technology to the traded goods sector across countries. We examined correlations of 0.25 and 0.50. The role of nontradable goods emphasized in our model is not appreciable affected by changes in this correlation.

7 Conclusion

In this paper, we investigate the role that non-tradable goods play in helping an otherwise standard new-open economy macroeconomic model match various features of the data. In particular, we concentrate on the role of nontradable goods in helping the model account for the relative exchange rate volatility, the correlation of the exchange rate with both relative consumptions and terms of trade, and their influence on some other important moments. Given the work of Stockman and Tesar (1995), and the importance that non-tradable goods play in the economy, this analysis is a natural extension to existing work in open economy models. The overriding message is that non-tradable goods serve a useful role in bringing the model closer to the data. The presence of nontradable goods increases the volatility of the real and nominal exchange rate by close to fifty percent. Importantly, the increase in the volatility of the real exchange rate is due largely to increased volatility in traded goods prices rather than increased volatility in the relative price of non-tradable goods across countries. Further, the presence of non-tradable goods reduces the correlation of the real exchange rate with relative consumptions, although our benchmark model is still at odds with the very low and often negative correlations that are found in the data.

[20]For elasticity values above 0.85, foreign consumption still increases relative to domestic consumption in response to a positive productivity shock to the traded goods sector in the home country but the real exchange rate appreciates, implying a positive correlation between these two variables.

We find that non-tradable goods has three other important implications in our model. First, the presence of nontradable goods helps match the cross country correlations of output and consumption, increasing the correlations between foreign and domestic output and reducing the correlation between consumption levels across countries. Second, contrary to a large literarure in open economy macro models where incomplete asset markets generate economic behavior similar to a complete asset markets economy, the presence of nontradable goods in our model generates a substantial difference in economic behavior between the two asset structures. Third, alternative assumptions regarding the way in which firms price their goods are largely inconsequential for the properties of aggregate variables in our model, other than the terms of trade. That is, for variables other than the terms of trade, the implications of our model are unaffected by whether firms set prices in the currency of the buyer or in their own currency. The terms of trade, however, behaves in a more realistic manner under producer currency pricing.

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Figure 1: Benchmark Economy - positive shock to z_N

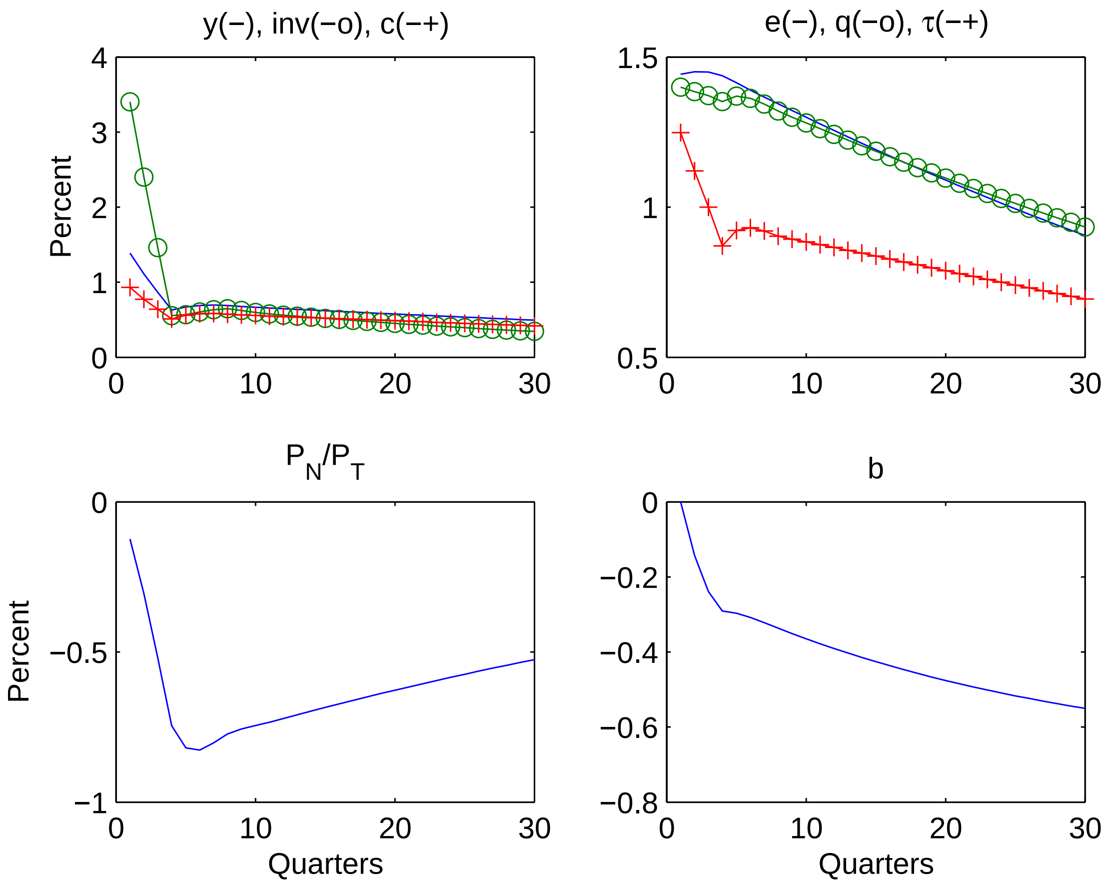

Figure 2: Benchmark Economy - positive shock to z_T

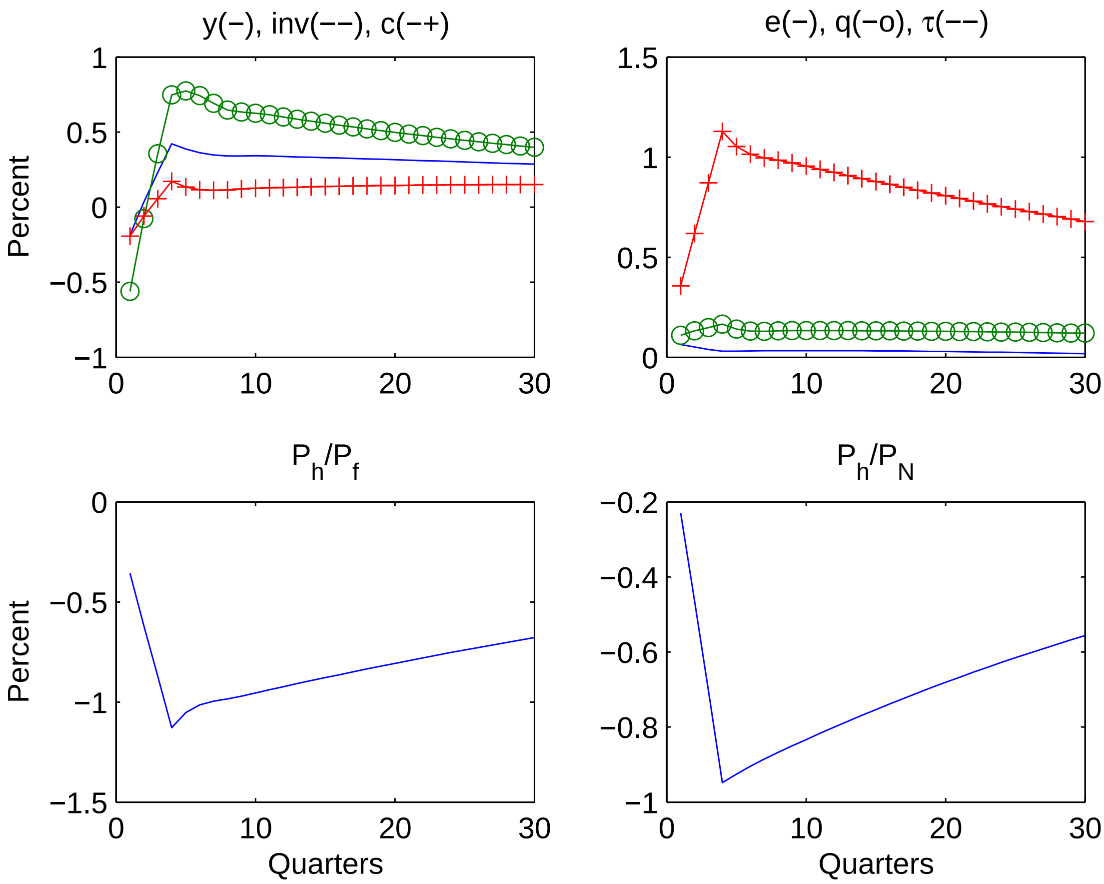

Figure 3: PCP versus LCP - positive shock to z_T

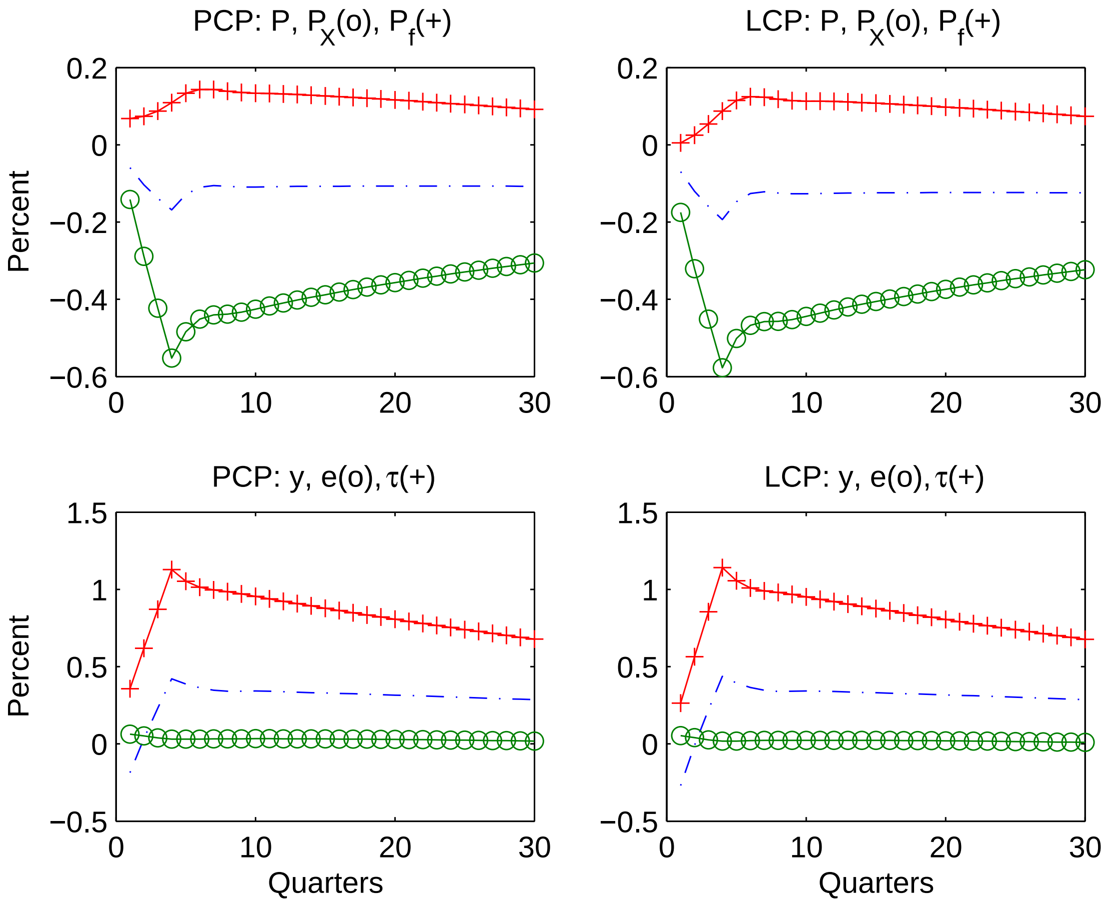

Figure 4: PCP versus LCP - positive shock to z_N