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Why Are Business Cycles Alike Across Exchange-Rate Regimes?[1]

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ABSTRACT

Since the adoption of flexible exchange rates in the early 1970s, real exchange rates have been much more volatile than they were under Bretton Woods. However, the literature showed that the volatilities of most other macroeconomic variables have not been affected by the change in exchange-rate regime. This poses a puzzle for standard international business cycle models. In this paper, we study this puzzle by developing a two-country, two-sector model with nominal rigidities featuring deviations from the law of one price because a fraction of firms set prices in buyers' currencies. We show that a model with such building blocks can improve the match between the model and the data across exchange-rate regimes. By partially insulating goods markets across countries and thus mitigating the international expenditure-switching effect, local currency pricing considerably dampens the responses of net exports to shocks hitting the economies therefore helping to account for the puzzle.

JEL classification: E32, E52, F31, F33, F41.

Keywords: equilibrium business cycle, price-adjustment costs, exchange-rate regime, exchange rate volatility.

1. Introduction

It is a well-established fact in international finance that the exchange-rate regime has non-neutral effects, since it affects the behavior of the real exchange rate. For instance, real exchange rates have been much more variable under the current managed float than they were under the Bretton Woods system.[1] There is also overwhelming evidence that, since 1973, large swings in nominal and real exchange rates have been closely correlated while ratios of price indices have been fairly stable. Many economists view this as evidence that price rigidities matter and that they should be one of the basic ingredients in any theory of international economic fluctuations.

However, a second, more puzzling set of stylized facts was pointed out by Baxter and Stockman (1989). For a range of countries, they show that the statistical properties of most other macroeconomic variables under the current managed float have remained very similar to what they were under Bretton Woods.[2] This evidence poses a serious challenge to any open-economy business cycle model, with or without nominal rigidities, in which relative prices (such as the real exchange rate) play a critical role in the allocation of real quantities. In these models, one would *a priori* expect a change in the volatility of the real exchange rate to be associated with a change in that of other macroeconomic series. For instance, in a typical two-country business cycle model in which each country is specialized in the production of one good, Backus et al. (1995) showed that the terms of trade are equal to the marginal rate of substitution between these two goods. As a result, movements in the terms of trade are linked to movements in the import ratio, namely the ratio of imports to output minus exports. Therefore, more volatile relative prices will be associated with, at least, more volatile quantities.[3] They concluded that "the issue is how to account for the sharp increase in price variability without generating a similar increase in the variability of quantities."

[1] Stockman (1983) and Mussa (1986), among others, documented those non-neutral effects of exchange-rate regimes.

[2] Flood and Rose (1995) showed that the increase in the volatility of the nominal exchange rate across exchange-rate systems has no statistical counterpart in that of any "traditional" fundamental suggested by monetary models of the exchange rate. Basu and Taylor (1999) and Sopraseuth (1999) confirmed these findings for both the Gold Standard period and the European Exchange Rate Mechanism.

[3] Backus et al. (1995) documented that the variability of the terms of trade has been higher in the post-Bretton Woods period than before by a factor of three, while that of the import ratio has increased by a much smaller amount (see Table 11.7, page 350).

The goal of this paper is to quantitatively account for this puzzle by introducing price rigidity and local currency pricing (LCP) in an otherwise standard dynamic general equilibrium model. In studying the impact on equilibrium allocations of some firms' ability to price discriminate across countries, we follow a recent strand in the open-economy literature on flexible exchange-rate regimes. In a theoretical paper, Betts and Devereux (2000) showed that preset prices in the buyers' currency may magnify the volatility of real and nominal exchange rates for a given pattern of money supply.[4] In quantitative contributions, Kollman (1997), studying a (semi)small open economy, and Chari et al. (2000), in the case of a two-country world, found that price stickiness in the buyer's currency can generate real exchange rates as volatile as in the data under a float. Since these features also lead to an imperfect pass-through of exchange-rate movements to consumer prices, they can mitigate the effects of exchange-rate changes on equilibrium allocations, making a model with such building blocks potentially capable of accounting for the above stylized facts. Moreover, consistent with the growing empirical evidence, such an environment generates deviations from purchasing power parity (PPP) that arise from a failure of the law of one price (LOP).[5]

In particular, we analyze the effects of different exchange-rate arrangements on the business cycle properties in a calibrated two-country, two-sector, stochastic equilibrium model in which some firms price-to-market and face convex price-adjustment costs. We examine a two-sector model for two reasons. The first relates to the evidence of a whole range of pricing behavior. By introducing two sectors with different speeds of price-adjustment, we capture this aspect of the data and view the findings of our model as *quantitatively* more convincing.[6] The second reason is that, on one hand, there is some evidence that a great deal of traded goods are homogeneous. For instance, Rauch (1999) calculated that in 1990 the trade share of homogeneous commodities among 63 countries ranged from 33 to 35 percent.

The main result of the paper is that the model is able to account for the empirical fact that more variability in real exchange rates does not get transmitted to other macroeconomic variables. As conjectured, LCP is important to this finding. Setting prices in the buyer's currency increases the volatility of the

[4] Devereux (1997) provides an excellent survey of the relevant ideas. In the late 1980s, pricing-to-market (PTM) was extensively studied in the trade literature as a possible explanation for the subdued response of the U.S. trade deficit to the devaluation of the U.S. dollar. Goldberg and Knetter (1997) survey the evidence about PTM.

[5] See e.g., Rogoff (1996) and Engel (1999).

[6] Wynne (1994) surveys the relevant evidence.

real exchange rate under a float while only marginally affecting the volatility of quantities across exchange-rate regimes. We show that this is not the case when firms do not price-discriminate: for instance, the volatility of net exports increases dramatically under a float relative to a fixed exchange-rate regime. LCP weakens the expenditure switching effect monetary policy shocks bring about under price rigidity, since movements in nominal exchange rates are not fully passed through to international prices. As a result, large variations in exchange rates are not necessarily associated with large movements in net exports (or other real quantities). However, one drawback of our model is that it can match the actual real exchange rate volatility under flexible exchange rates only by making consumption too volatile.

The decomposition of the variance of the real exchange rate, under each exchange-rate arrangement, into the variance of relative prices (consumption) in each country and their covariance also reveals the workings of the model. The increased volatility of the real exchange rate, when the nominal exchange rate is allowed to float, is mainly due to a fall in the covariance of relative prices (consumption) across countries. Therefore, since the variability of relative prices (consumption) is approximately unchanged across exchange-rate regimes, so is the variability of output and consumption.

Finally, we check the robustness of these results along several important dimensions, including the modeling of monetary policy and changes in the benchmark calibration. For instance, we show that the presence of two sectors with different pricing behavior is found not to be quantitatively crucial. In addition, assuming that the money supply follows a forward-looking interest-rate rule, rather than some exogenous stochastic process, as often assumed in the business cycle literature, turns out to impinge only on the variability of the real exchange relative to that of output.

Related papers include Monacelli (1998) and Duarte (2000). In a (semi)small open economy with Calvo price setting, Monacelli (1998) accounts for the increase in the variability of the real exchange rate under a managed float. Nevertheless, this attempt is only partially successful; for instance, the volatility of the trade balance turns out to be affected by the change in the exchange rate regime. Duarte (2000) studies how incomplete asset markets bear on this issue in a two-country model with no capital accumulation.

The rest of the paper is organized as follows. Section 2 describes the structure of the model and its workings; in Section 3 we discuss its calibration procedure. Business cycle statistics for the baseline model are presented in Section 4, while sensitivity analysis is conducted in Section 5. Finally, Section 6 offers concluding remarks.

2. The Model

Building from the work of Obstfeld and Rogoff (1995) and Ohanian et al. (1995), we model a two-country world in which each economy is composed of two sectors: one sector produces a homogeneous good, which we assume to be identical across countries, while the other sector is specialized in the production of a set of differentiated products. Specifically, the differentiated goods sector comprises a continuum of monopolistic firms, each producing a distinct differentiated good using labor and capital. These firms, contrary to the firms in the competitive sector, face convex price-adjustment costs of the type analyzed in Rotemberg (1982). We assume that, because of barriers to trade, monopolistic firms are able to price-discriminate across markets. The homogeneous good, which is perfectly traded in world markets, is also produced using capital and labor. Capital and labor are mobile across sectors. For simplicity, we assume that investment is made in the homogeneous good only. To generate plausible investment volatility, we postulate a cost to adjusting the amount of capital in a country, as in Baxter and Crucini (1993). We now describe the model in more detail.

2.1. Preferences

A representative agent inhabits each economy. The agent maximizes his expected lifetime utility as given by[7]

$$E_0 \left[\sum_{t=0}^{\infty} \beta^t U \left(C^T, C^M, \frac{M'}{P}, (1-H) \right) \right], \tag{2.1}$$

where C^T represents the agent's consumption of the homogeneous good, H represents the agent's supply of labor, M' denotes the agent's demand for nominal money balances, P is the country's price index, and C^M is an index of consumption of differentiated home and foreign goods given by

[7] In the text, a superscript prime variable will denote a time $t+1$ variable, whereas a variable with no superscript represents a time t variable. Foreign variables will be denoted by an asterisk. A superscript T represents the perfectly competitive good, while a superscript M denotes the monopolistic sector.

$$C^M \equiv \left(a_H \left[\int_0^1 (c(h))^\theta dh \right]^{\omega/\theta} + a_F \left[\int_0^1 (c(f))^\theta df \right]^{\omega/\theta} \right)^{\frac{1}{\omega}}, \tag{2.2}$$

where $c(h)$ ($c(f)$) is the agent's consumption of the home (foreign) brand h (f) of the differentiated good at time t. There is a continuum of these goods, with measure one. Total consumption is defined according to a Cobb-Douglas aggregator, $C \equiv (C^T)^\gamma (C^M)^{1-\gamma}$. Preferences and consumption of the foreign representative agent, C^*, are defined in a similar way.

The demand for the brands h and f of the home and foreign differentiated goods is obtained by maximizing the differentiated good consumption index subject to expenditure:

$$c(h) = \left(\frac{p(h)}{P^H} \right)^{-\frac{1}{1-\theta}} \left(\frac{P^H}{a_H P^M} \right)^{-\frac{1}{1-\omega}} C^M, \tag{2.3}$$

$$c(f) = \left(\frac{p(f)}{P^F} \right)^{-\frac{1}{1-\theta}} \left(\frac{P^F}{a_F P^M} \right)^{-\frac{1}{1-\omega}} C^M, \tag{2.4}$$

where $p(h)$ $(p(f))$ is the home currency price of the home-produced (foreign-produced) brand h (f) of the differentiated good.

P^M, P^H and P^F are the standard utility-based price indices:

$$P^M = \left[a_H^{\frac{1}{1-\omega}} \left(P^H \right)^{-\frac{\omega}{1-\omega}} + a_F^{\frac{1}{1-\omega}} \left(P^F \right)^{-\frac{\omega}{1-\omega}} \right]^{-\frac{1-\omega}{\omega}}, \tag{2.5}$$

$$P^H = \left[\int_0^1 p(h)^{\frac{\theta}{\theta-1}} dh \right]^{\frac{\theta-1}{\theta}}, \quad P^F = \left[\int_0^1 p(f)^{\frac{\theta}{\theta-1}} df \right]^{\frac{\theta-1}{\theta}}. \tag{2.6}$$

Finally, the overall price index is given by $P = \dfrac{(P^T)^\gamma (P^M)^{1-\gamma}}{\gamma^\gamma (1-\gamma)^{1-\gamma}}$.

2.2. Production Technologies

The production of the homogeneous and differentiated goods requires combining labor and capital using Cobb-Douglas production functions:

$$Y^T = A \left(K^T \right)^\rho \left(H^T \right)^{1-\rho}, \quad 0 < \rho < 1, \tag{2.7}$$

$$Y(h) = A\left(K(h)\right)^{\alpha}\left(H(h)\right)^{1-\alpha}, \quad 0 < \alpha < 1, \forall h, \tag{2.8}$$

where A represents an economy-wide, country-specific random technology shock.[8]

Capital accumulation is assumed to be carried out in the homogenous good only. In any given period, K will represent the capital stock in place in the home country. To have realistic investment flows (investment volatility tends to be too high otherwise), we follow Baxter and Crucini (1993) and assume that the law of motion of capital is subject to adjustment costs. The law of motion is described by the following equation:

$$K' = \Psi(I/K)K + (1-\delta)K \tag{2.9}$$

where δ is the depreciation rate and $\Psi(.)$ is an increasing, concave, and twice continuously differentiable function with two properties entailing no adjustment costs in steady state: $\Psi(\delta) = \delta$ and $\Psi'(\delta) = 1$.

2.3. The Firm in the Homogeneous Good Sector

The firm's problem is the usual one:

$$\max_{K^T, H^T} \Pi^T \equiv P^T A\left(K^T\right)^{\rho}\left(H^T\right)^{1-\rho} - R^T K^T - W^T H^T \tag{2.10}$$

where P^T, R^T, and W^T denote the nominal price of the purely tradable good, the rental rate of capital, and the nominal wage rate in the purely tradable good sector.

2.4. Firms in the Monopolistic Sector

We assume that firms in the monopolistic sector face a price-adjustment cost. When the firm decides to change the price it sets in the home (foreign) country, it must purchase an amount $\mu(h)$ ($\mu^*(h)$) of the homogeneous good. Following Hairault and Portier (1993), Rotemberg (1996), and Ireland (1997), the adjustment costs are given by the following quadratic functions:

$$\mu(h) = \frac{\xi}{2}\left(\frac{p_t(h)}{p_{t-1}(h)} - \pi\right)^2, \tag{2.11}$$

[8] We also examined a version of the model with sector-specific real shocks. The main findings of the paper were not affected, however, by this different stochastic structure.

and

$$\mu^*(h) = \frac{\xi}{2}\left(\frac{p_t^*(h)}{p_{t-1}^*(h)} - \pi^*\right)^2. \qquad (2.12)$$

Therefore, there are no costs to adjusting prices when the steady state inflation rate π prevails. Because of this cost, a temporary decrease in the growth rate of the money supply will lead to a gradual fall in the inflation rate and to a decrease of the monopolistic good output below its steady-state value.

This quadratic adjustment cost is not amenable to standard menu cost stories, emphasizing the fixed cost of price changes. Rotemberg (1982) rationalizes it by pointing to the adverse effects of price changes on customer-firm relationships, which increase in magnitude with the size of the price change.[9] Moreover, he shows that the implications of this setting for the aggregate dynamics of inflation are equivalent to those of the popular model of price rigidities developed by Calvo (1983) and often used in the open economy literature, e.g., in Kollman (1997). The quadratic cost is also consistent with the microeconomic evidence that some firms change their prices by very small amounts (Rotemberg, 1996). In any case, as stressed by Ireland (1997), this approach represents a tractable way of making individual nominal goods prices respond only gradually to nominal disturbances, allowing the monetary authority to affect aggregate activity in the short run. Furthermore, by having two sectors with different price flexibility, we can capture some aspects of these findings.

The (postulated) presence of trade barriers makes it possible for firms to price-to-market, by choosing $p(h)$, the home-currency price they charge in the home market, to be different from $p(f)$, the foreign-currency price they charge foreign consumers. Specifically, because of the presence of a price-adjustment cost, firms choose prices and inputs to maximize profits solving the following dynamic programming problem:

[9] For instance, suppose consumers have imperfect information about the distribution of prices and that this information is costly to acquire. In such an environment, firms may prefer to make frequent small price changes rather than sporadic large ones. On the one hand, a firm may be unwilling to raise its price by a large amount for fear of antagonizing consumers and inducing them to search for better price offers from its competitors. On the other hand, a firm may also be reluctant to reduce its price by a large amount in such an environment. The cost for consumers to look for better prices gives an incentive to the firm to reduce its price by a smaller amount than in a world of perfect information.

$$J(p_{_{-1}}(h), p^*_{_{-1}}(h); s) = \max_{p(h),p^*(h),K(h),H(h)} \left\{\Delta\Pi(h) + E\left[\Delta' J\left(p(h), p^*(h); s'\right)\right]\right\} \tag{2.13}$$

subject to (2.3) and its foreign counterpart, (2.8) and

$$\Pi(h) = p(h)c(h) + ep^*(h)c^*(h) - R^M K(h) - W^M H(h) - P^T(\mu(h) + \mu^*(h)), \tag{2.14}$$

$$c(h) + c^*(h) \geq Y(h), \tag{2.15}$$

where $s \equiv (A, A^*, g, g^*, PD^m_{t-1}, PD^{*m}_{t-1})$ denotes the aggregate state of the world in period t, with g (g^*) denoting the domestic (foreign) growth rate of money and PD^m (PD^{*m}_{t-1}) representing the distributions of differentiated goods' prices in the domestic (foreign) economy. As markets are complete both domestically and internationally, in equilibrium Δ equals the pricing kernel for contingent claims.

2.5. The Household

Each period the household decides how much labor to supply to the monopolistic sector, ϕH, and to the competitive sector, $(1-\phi)H$, at the nominal wages W^M and W^T, where $0 < \phi < 1$. Similarly, the household supplies a fraction, ν, of capital to the monopolistic sector and a fraction, $(1-\nu)$, to the competitive sector at the nominal rental rates R^M and R^T. In addition to the factor payments, the household's wealth comprises nominal money balances M; contingent one-period nominal bonds denominated in the home currency $B(s)$ - which pay one unit of home currency if state s occurs and 0 otherwise; profits from the monopolistic firms $\int_0^1 \Pi(h)dh$; a governmental lump-sum tax or transfer T. The household must decide how much of its wealth to allocate to the consumption of the homogeneous and differentiated goods and how much to invest and save in the form of bonds and nominal money balances, facing the following nominal budget constraint:

$$P^T\left(C^T + I\right) + P^M C^M + \int_{s'} P_b(s', s)B(s')ds' + M' = \Omega \tag{2.16}$$

where $P_b(s', s)$ is the price of the bond contingent on the state s' occurring at time $t+1$, given the state of the world, s, today. The agent's wealth follows the law of motion:

$$\begin{aligned}\Omega' \;=\;& W^{M'}\phi' H' + W^{T'}(1-\phi')H' + R^{M'}\nu' K' + R^{T'}(1-\nu')K' \\ &+B(s') + M' + \int_0^1 \Pi'(h)dh + P^{T'}T'\end{aligned} \tag{2.17}$$

The household's problem can be written as the following dynamic programming problem:

$$V(\Omega; s) = \max_{C^T, C^M, B(s'), M', H, I, K', \nu, \phi} \left\{ U\left(C^T, C^M, \frac{M'}{P}, (1-H) \right) + \beta E\left[V(\Omega'; s') \right] \right\} \tag{2.18}$$

subject to (2.16), (2.17), and the law of motion for capital given by (2.9).

2.6. Government

Each period the government makes a lump-sum transfer or collects a lump-sum tax (expressed in units of the tradable good) given by:

$$T = \left(\overline{M}' - \overline{M} \right)$$

The money supply evolves according to:

$$\overline{M}' = (1+g)\overline{M}$$

where the growth rate of money g will depend on the assumed monetary reaction function.

2.7. Equilibrium

2.7.1. Definition and Characterization

We focus on the equilibrium characterized by symmetry in the monopolistically competitive sector, defined as follows:[10]

- a set of decision rules for the representative household and the foreign equivalent, $C^T(\Omega; s)$, $C^M(\Omega; s)$, $B(\Omega; s')$, $M'(\Omega; s)$, $h(\Omega; s)$, $I(\Omega; s)$, $K'(\Omega; s)$, $\nu(\Omega; s)$, and $\phi(\Omega; s)$, solving the household's problem;
- a capital demand rule, $K(h; p_{-1}(h), p^*_{-1}(h); s)$, a labor demand rule $H(h; p_{-1}(h), p^*_{-1}(h); s)$, and pricing functions $p(h; p_{-1}(h), p^*_{-1}(h); s)$ and $p^*(h; p_{-1}(h), p^*_{-1}(h); s)$ solving the monopolistic firm's problem;

[10] To save on notation, we do not show the conditions for the foreign country.

- a capital demand rule, $K^T(s)$ and a labor demand rule $H^T(s)$ solving the competitive firm's problem, taking prices, $P^T(s)$, $W^T(s)$ and $R^T(s)$, as given.

- $p(h; p_{-1}(h), p^*_{-1}(h); s) = p(p_{-1}, p^*_{-1}; s)$ and $p^*(h; p_{-1}(h), p^*_{-1}(h); s) = p^*(p_{-1}, p^*_{-1}; s)$ for all h.

- $p(p_{-1}, p^*_{-1}; s)$, $p^*(p_{-1}, p^*_{-1}; s)$, $P_b(s', s)$, $P^T(s), W^T(s)$, $R^T(s)$, $W^M(s)$, and $R^M(s)$ are such that the goods, money, bonds, and input markets clear.

Since the homogeneous good is perfectly traded on world markets, the law of one price holds:

$$P^T(s) = e(s)P^{*T}(s). \tag{2.19}$$

As usual, the (CPI based) real exchange rate is defined as:

$$z(s) \equiv \frac{e(s)P^*(s)}{P(s)}. \tag{2.20}$$

Because of *LCP*, changes in the real exchange rate come from deviations from the *LOP* in monopolistic goods. Using the household's first order conditions, the real exchange rate can be written as:[11]

$$z(s) = \left(\frac{P^{*M}(s)/P^{*T}(s)}{P^M(s)/P^T(s)}\right)^{1-\gamma} = \left(\frac{q^*(s)}{q(s)}\right)^{1-\gamma}, \tag{2.21}$$

where, because of the Cobb-Douglas consumption aggregator:

$$q(s) = \frac{1-\gamma}{\gamma}\left(\frac{C^T(s)}{C^M(s)}\right).$$

Therefore, the variance of the logarithm of $z(s)$ can be decomposed in the following way:

$$Var(\log z) = (1-\gamma)^2\left[Var(\log q^*) + Var(\log q) - 2Cov(\log q^*, \log q)\right]. \tag{2.22}$$

[11] The theoretical prediction that bilateral real exchange rates should be highly correlated with cross-country consumption ratios is common to all equilibrium models, irrespective of the degree of pass-through assumed. Backus and Smith (1993) and Kollman (1995) showed that this prediction hardly finds support in the data.

Two observations are in order. First, assuming $\frac{C^{*T}(s)}{C^{T}(s)}$ is roughly constant, the smaller the consumption share γ of the homogeneous good and the lower the cross-country covariance of relative (log) consumption of the monopolistic good, the more volatile $z(s)$ is.[12] Therefore, provided consumption is positively correlated across countries as it is in the data, this model can realistically generate a real exchange rate at most as volatile as relative consumption.[13]

Second, since the foreign country imports home monetary policy when it pegs its nominal exchange rate, relative consumption becomes perfectly correlated in response to both real and monetary shocks. As a result, the covariance between domestic and foreign consumption increases to such an extent that the variance of $z(s)$ is approximately zero. Therefore, for the model to successfully replicate the relevant stylized facts, the model's variances of domestic and foreign consumption of the monopolistic good should remain roughly invariant across currency regimes. We demonstrate below that the model generates very similar consumption variances across exchange-rate regimes.

3. Calibration

In order to be able to solve the model we have to pick baseline values for the parameters. The top panel of Table 1 reports our benchmark choices, which we assume symmetric across the two countries. Several parameters' values are similar to those used in Chari et al. (2000), who calibrate their model to the United States and Europe. In contrast, because of data availability, we will compare our model to the G7 countries' evidence over the Bretton Woods and post-Bretton Woods periods.[14] In Section 5, we conduct some sensitivity analysis to assess the robustness of our results, under the benchmark calibration.

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[12] When the utility function is separable between consumption and real balances and logarithmic, $\frac{C^{*T}(s)}{C^{T}(s)}$ is indeed constant.

[13] As shown by Chari et al. (2000), when all good markets are segmented ($\gamma = 0$), the real exchange rate is given by a different expression, not involving within-country relative prices. In this case, the real exchange-rate volatility is roughly proportional to that of relative consumption across countries, with the constant of proportionality given by the relative risk aversion coefficient.

[14] The G7 countries are the USA, Japan, Germany, France, the United Kingdom, Italy and Canada.

Preferences Consider first the preference parameters. We adopt a utility function of the following form, separable between the consumption-money aggregate and leisure:

$$U\left(C,\frac{M'}{P},H\right) = \frac{1}{1-\eta}\left[\left(\psi\left(\left(C^{T}\right)^{\gamma}\left(C^{M}\right)^{1-\gamma}\right)^{\frac{\sigma-1}{\sigma}}+(1-\psi)\left(\frac{M'}{P}\right)^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}}\right]^{1-\eta} + \upsilon\frac{(1-H)^{1-\varepsilon}}{1-\varepsilon}. \tag{3.1}$$

The leisure parameters ε and υ are set so as to give an elasticity of labor supply, with marginal utility held constant, of 2 and a working time of one-quarter of the total time. We set to curvature parameter η to 2.

Following Chari et al. (2000), we set ψ to 0.94. The interest elasticity of money demand, σ, is known to be small but positive. We use Ireland's (1997) estimate and set it equal to 0.159. The relative share of the differentiated consumption good in steady-state consumption $(1-\gamma)$ is set to 0.58, which is the average of Rauch's (1999) estimate for differentiated products over the last three decades.[15] The discount factor β is set to 0.9901, implying a quarterly real interest rate of 1 percent.

We set θ to 6.17, yielding a value of 1.19 for the steady-state markup, equal to that estimated by Morrison (1990); this value is standard in the literature. The elasticity of substitution between monopolistic home and foreign goods is $\frac{1}{1-\omega}$; we use the estimate of Backus et al. (1995) and set it to 1.5. We set the parameters a_H and a_F, in the consumption aggregator, determining the steady state monopolistic good import share, to 0.7607 and 0.2393. This corresponds to the parameters in Chari et al. (2000), in their high export share exercise, and is also in line with the estimates in Kollman (1997) for the G7 countries.

Production Consider next the technology parameters for the homogeneous and the differentiated goods. Since all the goods are traded, we used Stockman and Tesar's (1995) estimate of the labor share in the production of tradable goods and set $(1-\rho)$ and $(1-\alpha)$ to 0.61.

We set the second derivative of the capital adjustment cost function in steady state, $\phi''(\delta)$, so that the volatility of investment relative to that of output is in

[15] In Section 5.1 we analyze the implications of different values of this parameter.

line with the data. Following Ireland (1997), we set the parameter of the price-adjustment cost function $\xi = 50$. Ireland shows that such a parametrization leads firms to contemporaneously erase 10 percent of the discounted gap between their current and expected future prices and the price that would be optimal in the absence of adjustment costs, a value suggested by King and Watson (1996).

Real Shocks The economy-wide technology shocks are assumed to follow a bivariate autoregressive process:

$$\mathbf{A}^{'} = \boldsymbol{\lambda}\mathbf{A} + \boldsymbol{\epsilon}^{'}$$

where $\mathbf{A} \equiv (A, A^{*})^{'}$, $\boldsymbol{\epsilon} \equiv (\epsilon, \epsilon^{*})^{'}$ and $\boldsymbol{\lambda}$ is a matrix of coefficients. For our benchmark calibration, we follow Backus et al. (1995) and use their estimates of $\boldsymbol{\lambda}$ for the US and Europe:

$$\boldsymbol{\lambda} = \begin{bmatrix} 0.906 & 0.088 \\ 0.088 & 0.906 \end{bmatrix},$$

and their values for the standard deviation and cross-correlation of the shocks (ϵ, ϵ^{*}), equal to .00852 and 0.258, respectively.

Monetary Processes The details of the monetary rules followed in the G7 countries are extensively discussed in the literature. A recently popular way to do so has been with an interest rate rule; thus we take as our benchmark the forward-looking instrument rules for the short-term interest rates estimated for the US and the other G7 countries by Clarida, Galì and Gertler (1998, 2000). Subsequently we assess how changing this benchmark affects our results.

Specifically, we assume that the monetary authority sets the nominal short-term interest rates according to the following feedback rule:

$$\log R_t = (1 - \alpha_R) \log \overline{R} + \alpha_R \log R_{t-1} + \alpha_\pi E_t(\widehat{\pi_{t+1}}) + \alpha_y E_t(\widehat{y_{t+1}}) + \varepsilon_{t,R}$$

where R, π, and y represent the short-term nominal interest rate, aggregate inflation, and aggregate output. As usual, $\widehat{x}$ denotes the deviation of that variable from its steady state level. Drawing from the estimates for the US in Clarida, Galì and Gertler (2000), regarding the period 1979:3-1996:4, we set $\alpha_R = 0.79$, $\alpha_\pi = 0.4515$, and $\alpha_y = 0.1953$.

We set the benchmark calibration of the standard deviation of $\varepsilon_{t,R}$ to 0.005, which is a middle ground between the estimates of Ireland (1997), McCallum and

Nelson (1999), and those found in Angeloni and Dedola (1999). Finally, since in the model the volatility of the real exchange rate is affected by the cross-correlation of consumption, the correlation of monetary shocks across countries is set such that the model matches the empirical cross-correlation of consumption between the US and the average of the other G7 countries since 1973.

4. Findings

We now assess the business cycle properties of our model economy under the two different exchange-rate regimes, focusing on the difference in the volatility of key variables. Throughout all the exercises, we define the fixed exchange rate regime as the one in which the foreign country (credibly) pegs its currency to that of the home country. We compute all the statistics by logging and filtering the data using the Hodrick and Prescott filter and averaging moments across 100 simulations, each running for as many periods as the actual fixed and floating historical periods (i.e., 52 and 116 quarters respectively). The H-P filtered statistics for the data, the baseline economy and some variations on that economy are reported in Tables 2, 4 and 5. The statistics for the data are all computed with the United States as the home country and the average of the other G7 countries as the foreign one.

In order to convey the extent of the puzzle highlighted by Stockman (1983), Mussa (1986), Baxter and Stockman (1989), and Flood and Rose (1995), Table 2 reports the standard deviations of the main macroeconomic variables and exchange rates for the US and the (average of) other G7 countries. The Table clearly shows that while the real and the nominal exchange rates have become much more volatile in the post-Bretton Woods era, we do not observe a similar change in the volatility of the other macroeconomic variables reported in the table. For instance, the standard deviations of output are roughly the same under the two periods for both the US and the average of the other G7 countries. Moreover, while consumption,employment, interest rates and US investment have become more volatile since 1973, this increased volatility pales compared to the increase in the standard deviation of the nominal and real exchange rate. Finally, the standard deviation of net exports (and of foreign investment) slightly fell after the demise of Bretton Woods. Figure 1 depicts the data for individual countries, yielding the same broad picture.

Overall, we find that the benchmark model can match the data qualitatively well. Comparing volatilities of variables under either a fixed or a flexible exchange-rate regime, Table 2 shows that the real exchange rate is clearly the variable most affected by a change in the currency regime: under a float it becomes roughly three times as volatile as foreign output. In general, as in the data, a flexible exchange rate regime brings about an increase in most variables' volatilities, both for the home and the foreign country, although none experiences changes in volatility as large as that of the real exchange rate. Only the volatilities of foreign output and employment and home investment slightly decrease.

However, quantitatively, on some dimensions the model is less successful. The second variable most affected by the exchange rate regime is net exports: its standard deviation increases by about fifty percent under the float compared to that when the foreign country pegs its currency. In the model, net exports are also more volatile when the currencies float than under the fixed exchange-rate regime, whereas the opposite occurs in the data.[16]

In addition, as we previously mentioned, both real and nominal exchange rates have been highly volatile under the current flexible exchange rate system. In fact, Table 2 reports that the standard deviation of either exchange rate is approximately 4 times that of output. Under our calibration, the model with a flexible exchange rate regime produces variability of the nominal and real exchange rates that are, respectively, 7.7 and 3.2 times the variability of home output. Therefore, the model succeeds in generating a volatile nominal exchange rate, and this translates into a variability of the real exchange rate relative to aggregate output that is only slightly smaller than that in the data. Nevertheless, this comes at a cost. Under the postulated rule for monetary policy, the volatility of some variables relative to that of output is not matched in the model: the money stock, the inflation rate and consumption are more volatile than in the data when the currencies float, although their volatility is barely affected by the exchange-rate regime.

Finally, while the real and the nominal exchange rates correlation is very high in the model – 0.82, close to that recorded in the data since 1973, equal to 0.95 – one important shortcoming is the negative cross-correlation of output, which results, as in most business cycle models, from the transfer of productive resources to the relatively more productive country in responses to real shocks.

[16] However, we will show below that the volatility of net exports increases much more drastically, from a fixed to a flexible exchange-rate regime, when firms do not price to market. In this sense, pricing-to-market improves the match of the model with the data.

Table 3
Ratios of Relative Prices' Second Moments across Exchange Rate Regimes

	$St.Dev.(q^*)$	$St.Dev.(q)$	$Cov(q^*, q)$
Fix vs. Float	1.15	1.08	1.98

The Behavior of Relative Prices across Countries Why are the variances of most macroeconomic series in our model, except that of the real exchange rate, unaffected by the exchange rate regime? One immediate reason is that the change in the exchange rate system impinges mainly on the covariance between domestic and foreign relative prices. Recall from Section 2.7 that we can write the variance of the real exchange rate as:

$$Var(\log z) = (1-\gamma)^2 \left[Var(\log q^*) + Var(\log q) - 2Cov(\log q^*, \log q) \right].$$

Under a flexible exchange rate regime, the domestic and foreign relative prices are barely correlated in response to a monetary shock and perfectly correlated in response to a real shock. Since the foreign country imports the home monetary policy when it pegs its nominal exchange rate, relative prices become perfectly correlated in response to both real and monetary shocks. Therefore, the covariance and the correlation of relative prices increase under a fixed exchange rate regime to such an extent that the variance of the real exchange rate is approximately zero.

Table 3 presents the ratios of the standard deviation and the covariance of domestic and foreign relative prices under the two exchange rate regimes. It shows that while the standard deviations of the domestic and foreign relative prices are approximately the same under the two currency regimes, the covariance between these two relative prices is two times higher when the nominal exchange rate is fixed. Therefore, because of the link between consumption and relative prices shown in Section 2.7, the fact that the volatility of relative prices is barely affected by the exchange-rate system explains why consumption and output are equally volatile whether the exchange rate is fixed or not.

5. Sensitivity Analysis

Here we examine the findings of our benchmark model by varying assumptions about some of the model's features. In particular, we study the importance of the monetary rule and the market structure for the model's results. We find that while, overall, our previous findings are fairly robust to changes in systematic monetary policy, *LCP* plays a crucial role in making quantities not sensitive to the exchange rate regime.

5.1. LCP and the Flexible Price Sector

As argued above, in our baseline calibration the volatility of the real exchange rate does not have an impact on the volatility of quantities because of the presence of firms pricing-to-market and because of a significant share of the competitive good. Basically, the combination of pricing-to-market and price rigidity in the buyer's currency mitigates the expenditure-switching effect, since movements in nominal exchange rates do not fully pass-through to the prices consumers face. As a result, large variations in exchange rates are not necessarily associated with as large movements in consumption, output, and net exports, as when firms do net set prices in buyers' currencies. Here, we want to shed some light on the contribution of these two features of the model, by investigating how changes in γ, the share of the purely competitive, flexible-price good, and the absence of *LCP* affect our results. We report the results of these two experiments in Table 4.[17]

5.1.1. *LCP*

Removing *LCP* has an important impact on the relative variability of quantities across exchange-rate regimes. Net exports are now over 4 times more volatile when the currencies float than under the fixed exchange-rate regime. The real exchange rate is also slightly less volatile. To better understand this result, Figure 2 compares the responses of the economies, with and without *LCP,* to a negative one standard-deviation shock to the domestic nominal interest rate.

Under *LCP*, the drop in the interest rate implies that the domestic growth rate of money and inflation rise on impact. Due to the presence of price-adjustment costs in the monopolistic sector, this leads the relative price of foreign differentiated goods in the home country to fall. As a result, home consumption of foreign

[17] We only report the statistics for the home country since the impact on foreign ones is very similar.

differentiated goods increases. Nevertheless, the fall in the price outweighs the increase in demand and home expenditure on foreign differentiated goods falls. Note that, because of *LCP*, the foreign economy is barely affected by a monetary shock in the home country.

When there is no *LCP*, the expenditure-switching effect is magnified. First, since the exchange rate depreciated, the relative price of foreign differentiated goods in the home country now rises. Nevertheless, home demand for these goods rises, since the monetary shock increases total domestic aggregate demand and this increase outweighs the negative impact of rising prices on demand. Similarly, since the foreign currency appreciates, home differentiated goods are now cheaper in the foreign country. As a result foreign demand for home differentiated goods rises. When there is no *LCP*, the response expenditure on imports is much larger than with *LCP*. As a result, the response (in absolute value) of net exports of differentiated goods is about four times larger when firms do not set prices in buyers' currencies. Therefore, *LCP* is important for the findings.

5.1.2. Two Sectors

In this exercise we reduce the size of the tradable sector to 1 percent, by setting $\gamma = 0.01$. Thus, the importance of nominal rigidity increases and since monetary shocks play a significant role in our environment, reducing the size of the competitive sector can potentially affect the result. However, we find that the size of the sectors does not have a significant impact on the findings across regimes, while it slightly affects absolute volatilities under a float.

5.2. Monetary Policy Rules

There is a lively debate over the most appropriate way to model monetary policy. Here we describe the properties of our model economy under different specifications of the monetary process. Specifically, we investigate how a money growth rule, a contemporaneous interest rate rule and changes in the home country systematic monetary policy across exchange rate regimes, similar to those documented for the US, affect our findings.

5.2.1. Money-Growth Rate Rule

In general, the equilibrium of the economy under the interest rate rule has a corresponding money growth process associated with it. Assuming this money growth process to be the policy rule, the equilibrium for this economy with this money growth is the same as that for an economy with the interest rate rule. Of course, such rules can be represented as either a function of both past endogenous variables and exogenous shocks or as a function of solely the history of exogenous shocks. Moreover, there is empirical evidence in support of the choice for the money growth rule. In particular, Christiano, Eichenbaum, and Evans (1998) have shown that a money growth process of the kind considered here is a good approximation to a process that implements their estimated interest rate rule.

Thus, we consider the implications of replacing our interest rate rule with a simple rule for money growth similar to those usually studied in the monetary business cycle literature, e.g., by Cooley and Hansen (1995) and Chari et al. (2000). In particular, we assume that the growth rate of the money stocks for both countries follows a process of the form:

$$\log g' = (1 - \rho_g) \log \overline{g} + \rho_g \log g + u', \tag{5.1}$$

where u' is a normally distributed, zero-mean shock. Each shock has a standard deviation of σ_u, and the shocks have a positive cross-correlation. The stochastic process for money in the foreign country is the same. Following Chari et al. (2000), we choose $\rho_g = 0.57$. In order to make results comparable to those under the benchmark calibration, we set the standard deviation of these shocks so that the nominal interest rate volatility is .67, the same as under the interest rate rule. As before, the cross-correlation of these shocks is chosen so as to produce a cross-correlation of consumption that is equal to that in the data. In Table 5, we report the results for this exercise in the columns labeled "Exogenous Money."

When we use this money-growth rule in our benchmark model, we basically obtain the same results as before. Briefly, this model moves the ratio of the volatilities of the main macroeconomic variables across regimes closer to those in the data, including net exports. In addition, consumption volatility is now lower than that of output. However, the model's nominal and real exchange rates are much less volatile than those in either the data or the benchmark model. The reason is that the growth rate of money is now much less volatile than under the forward-looking interest-rate rule, even though the nominal interest rate volatility is the same by construction. This leads to less volatile relative prices, which ultimately translate into a less volatile real exchange rate. As we will explain in the next experiment, this is due to the systematic response to shocks entailed by our benchmark, forward-looking rule.

5.2.2. Contemporaneous Interest-Rate Rule

In our second experiment we posit that monetary policy follows a more standard Taylor rule (Taylor, 1993), according to which short-term interest rates react to contemporaneous deviations of inflation and output from their target (steady state) values. In this exercise, we keep the same parametrization of the central bank's reaction function as under the benchmark case, but we assume that the monetary authority adjusts the nominal interest rate in response to contemporaneous movements in inflation and output. Tables 5 reports the results for this exercise in the columns labeled "Contemporaneous." Again, but for the real exchange rate, overall the exchange-rate regime does not significantly affect the volatilities of the model's variables. However, when the central bank follows a contemporaneous interest-rate rule, the standard deviation of the real exchange rate relative to that of output is much lower than under the forward-looking reaction function. Therefore, these results are similar to those under the money-growth rule.

Whether the reaction function of the central bank is forward looking or not therefore matters for the volatility of the real exchange rate, in our environment. Under this rule, the central bank is assumed to react to expected deviations of the inflation rate and output from their respective targets. Thus, when an unexpected shock hits the economy, the monetary authority does not respond to current deviations in inflation and output. In this environment in which some firms enjoy price flexibility while the others face price-adjustment costs, shocks have the maximum inflation and output effect on impact, as shown in Figure 3. The responses to an expansionary monetary shock of domestic aggregate inflation, aggregate output, relative prices, nominal interest rate, money growth and the real exchange rate under both types of interest-rate rules are reported.[18] The figure shows that under the forward-looking rule the central bank allows the nominal interest rate to fall more on impact, making current inflation and output deviate more from their steady state values than under the contemporaneous rule. As a result, the domestic relative price of differentiated goods falls more and the extent of the depreciation of the real exchange rate is more pronounced under the forward-looking rule. Since the response of output is about the same under either rule, the real exchange rate depreciates more relative to output when the central bank is forward looking. This difference between the rules occurs because the inflation rate displays very low persistence, quickly returning to the steady

[18] The intuition is similar for a real shock.

state value following a shock.

5.2.3. Different Monetary Rule Under the Fixed Exchange-Rate Regime

Finally, there is some presumption that systematic monetary policy may have undergone significant changes in the last few decades. For instance, Clarida et al. (2000) have shown that the monetary policy rule followed by the Fed have changed in the 1980s with respect to the Bretton Woods period. The rule they estimate over this period is rather different from the one prevailing under Volcker and Greenspan; they argue that it may have entailed a less effective stabilization in response to shocks hitting the economy, making macroeconomic variables unduly volatile.

Therefore, in the following exercise we assume that, under the fixed exchange-rate regime, the domestic central bank follows a forward-looking interest-rate rule identical to the one in the benchmark calibration, but with the following parameters: $\alpha_R = 0.87$, $\alpha_\pi = 0.1978$, and $\alpha_y = 0.0322$. One aspect of this rule is that the central bank is not as prone to fight inflation by raising the nominal interest rate. These parameters correspond to those estimated in Clarida et al. (2000) under the Miller chairmanship in the 1960s, but for the coefficient on the lagged interest rate. Relative to their findings, we had to increase the estimate on the lagged interest rate (0.87 relative to 0.77). Clarida et. al. (2000) and others have argued that models with an interest-rate rule with properties such as those in the pre-Volcker era can lead to multiple equilibria. This is indeed the case in our environment when we use their estimated $\alpha_R = 0.77$. However, the model has a unique equilibrium when we raise α_R to 0.87. To concentrate on the study of unique rational expectation equilibria, we therefore chose this parameterization. In Table 5, we report the results for this exercise in the columns labeled "Two rules." Although no variable experiences a change in volatility similar to that of the real exchange rate, in general we find that, under the flexible exchange-rate regime and the benchmark rule, all the variables are now about 20 to 25 percent less volatile than when the foreign currency is pegged. Therefore, we find that changes in systematic monetary policy across exchange-rate regimes, similar to those recently pointed out in the literature on the stability of monetary reaction functions, can have a quantitatively important role in bridging the gap between the equilibrium models and the evidence across regimes.

6. Concluding Remarks

The recent literature on the volatility of the real exchange rate has suggested that there is some hope for a "traditional" macroeconomic approach to the real exchange rate. Following this insight, this paper has developed a somewhat standard general equilibrium model, featuring deviations from the law of one price and nominal price rigidities. We found it quantitatively able to go some way in accounting for both the dramatic increase in the relative volatility of the nominal and real exchange rates since the fall of the Bretton Woods system, and the relative stability in the volatility of most other macroeconomic variables. One of the main mechanisms behind this result is the combination of local currency pricing and price rigidity in the buyer's currency, as fluctuations in nominal exchange rates are not fully passed through to the prices consumers face. Consequently, large variations in exchange rates are not necessarily associated with large movements in quantities. This feature is quantitatively crucial, since it particularly decreases the volatility of net exports, under floating exchange rates. In addition, although we find that a combination of LCP and price rigidity helps bridge the gap between the model and the data, these features cannot by themselves account for the entire extent of the puzzle once we allow monetary policy to change significantly across exchange-rate regimes in a direction that is consistent with the recent evidence on the stability of monetary reaction functions.

Clearly, however, this analysis is not free of problems; for instance, our equilibrium model can generate significant real exchange rate variability only under a forward-looking central bank, and at the cost of generating too volatile consumption and inflation rates. Finally, in our model the increase in variability of the real exchange rate under a flexible exchange rate regime is brought about by a fall in the covariance of within-country relative prices of goods that are subject to price-discrimination; the currency regime has barely any effect on the variance of these relative prices. Therefore, an important task for future research would be to provide direct evidence of the specific relationships among exchange-rate arrangements, sectorial market structure, and the properties of relative price movements.

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7. Appendix

Household A solution to the household's problem satisfies:

$$U_1\left(C^T, C^M, \frac{M^{'}}{P}, (1-H)\right) = \lambda P^T \tag{7.1}$$

$$U_2\left(C^T, C^M, \frac{M^{'}}{P}, (1-H)\right) = \lambda P^M \tag{7.2}$$

$$\lambda P_b(s^{'}, s) = S(s^{'}, s)\beta V_1(\Omega^{'}; s') \tag{7.3}$$

$$\lambda = U_3\left(C^T, C^M, \frac{M^{'}}{P}, (1-H)\right) + \beta E\left(V_1(\Omega^{'}; s')\right) \tag{7.4}$$

$$\lambda(W^M\phi + W^T(1-\phi)) = U_4\left(C^T, C^M, \frac{M^{'}}{P}, (1-H)\right) \tag{7.5}$$

$$\chi\Psi'(I/K) = \lambda P^T \tag{7.6}$$

$$\chi = \beta E\left[\lambda'(\nu R^{M^{'}} + (1-\nu)R^{T^{'}})\right] + \beta E\left[\chi^{'}(\Psi(I/K) - \Psi'(I/K)(I/K) + (1-\delta)\right] \tag{7.7}$$

$$W^M = W^T \tag{7.8}$$

$$R^M = R^T \tag{7.9}$$

$$V_1(\Omega; s) = \lambda \tag{7.10}$$

where U_i and V_i represent the partial derivative of the utility function and the value function with respect to their ith argument, and χ is the multiplier associated with the capital evolution equation (2.7). $S(s^{'}, s)$ denotes the transition function governing the state of the world. It gives the probability of state $s^{'}$ occurring at time $t+1$, given that the world is in state s at time t.

Firms Similarly to the competitive firm, the problem of the monopolistic firm yields the following conditions:

$$\rho W^M = \zeta A(1-\alpha)\left(K(h)\right)^{\alpha}\left(H(h)\right)^{-\alpha} \tag{7.11}$$

$$\rho R^M = \zeta A\alpha\left(K(h)\right)^{\alpha-1}\left(H(h)\right)^{1-\alpha} \tag{7.12}$$

$$\frac{\Delta\theta}{1-\theta}\left(\frac{p(h)}{P^H}\right)^{-\frac{1}{1-\theta}}\left(\frac{P^H}{a_H P^M}\right)^{-\frac{1}{1-\omega}} C^M = -\Delta\left(P^T/p_{-1}(h)\right)\xi\left(\frac{p(h)}{p_{-1}(h)}-\pi,\right)$$
$$-E\left[\Delta'\left(P^{T'}/p(h)\right)\xi\left(\frac{p'(h)}{p(h)}-\pi,\right)\right]-\zeta\frac{1}{1-\theta}\left(\frac{p(h)}{P^H}\right)^{-\frac{1}{1-}}$$

$$\rho(1-\theta)\left(\frac{p^m_{f,h}(j)}{P^{m^*}}\right)^{-\theta} C^{m^*} = -\rho P^T\varphi_1\left(p^m_{f,h}(j), p^m_{-1f,h}(j)\right) \tag{7.14}$$
$$-E\left[\rho' P^{T'}\varphi_2\left(p^{m'}_{f,h}(j), p^m_{f,h}(j)\right)\right]-\eta\frac{\theta}{P^{m^*}}\left(\frac{p^m_{f,h}(j)}{P^{m^*}}\right)^{-\theta-1} C^{m^*}$$

where ζ is the multiplier related to the distribution of output across home and foreign markets (2.18), and φ_i is the partial derivative of the cost function with respect to its ith argument.

Conditions (2.38) and (2.39) are the standard conditions stipulating that the firm hires labor and capital until the marginal revenue of hiring one more unit equals its marginal cost. Equations (2.40) and (2.41) indicate that the firm selects prices $p^m_{h,h}(j)$ and $p^m_{f,h}(j)$ so that the marginal benefit of raising a price equals the marginal cost. In a symmetric equilibrium, these price-setting conditions become:

$$\rho(1-\theta)\left(\frac{p^m_{h,h}}{P^m}\right)^{-\theta} C^m = -\rho P^T\varphi_1\left(p^m_{h,h}, p^m_{-1h,h}\right) - E\left[\rho' P^{T'}\varphi_2(p^{m'}_{h,h}, p^m_{h,h})\right]$$
$$-\eta\theta\left(\frac{p^m_{h,h}}{P^m}\right)^{-\theta}\frac{C^m}{P^m} \tag{7.15}$$

and

$$\rho(1-\theta)\left(\frac{p^m_{f,h}}{P^{m^*}}\right)^{-\theta} C^{m^*} = -\rho P^T\varphi_1\left(p^m_{f,h}, p^m_{-1f,h}\right) - E\left[\rho' P^{T'}\varphi_2\left(p^{m'}_{f,h}, p^m_{f,h}\right)\right]$$
$$-\eta\theta\left(\frac{p^m_{f,h}}{P^{m^*}}\right)^{-\theta}\frac{C^{m^*}}{P^{m^*}} \tag{7.16}$$

By raising its price, the monopolistic firm benefits from the higher value of its output but bears the current and future costs of changing its price, as well as a lower current demand for its product.

Table 1
Parameter values

Benchmark Model	
Preferences	$\beta = .9901, \eta = 2, \psi = .94, \sigma = .159, \gamma = .42,$ $\omega = 1/3, \theta = 6.17, a_H = 0.7607, a_F = 0.2393$
Homogeneous good technology	$\alpha = .39, \Psi''(\delta) = -2.6$
Differentiated good technology	$\rho = .39, \xi = 50$
Technology shocks	$\lambda = \begin{bmatrix} 0.906 & 0.088 \\ 0.088 & 0.906 \end{bmatrix},$ $\sigma_\varepsilon = \sigma_{\varepsilon^*} = .00852, corr(\varepsilon, \varepsilon^*) = .258$
Forward looking Taylor rule	$\alpha_R = .79,\ \alpha_\pi = .4515, \alpha_y = .1953,$ $\sigma_{\varepsilon_R} = \sigma_{\varepsilon_R^*} = .005, corr(\varepsilon_R, \varepsilon_R^*) = .0046$
Variations	
Exogenous money	$\rho_g = .57, \sigma_u = \sigma_{u^*} = .007, corr(\varepsilon_R, \varepsilon_R^*) = -.006$
Contemporaneous Taylor rule	$\alpha_R = .79,\ \alpha_\pi = .4515, \alpha_y = .1953$ $\sigma_{\varepsilon_R} = \sigma_{\varepsilon_R^*} = .005, corr(\varepsilon_R, \varepsilon_R^*) = -0.01$
Two rules	$\alpha_R = .87,\ \alpha_\pi = .1978, \alpha_y = .0332$ $\sigma_{\varepsilon_R} = \sigma_{\varepsilon_R^*} = .005, corr(\varepsilon_R, \varepsilon_R^*) = .0046$

Table 2
Business Cycle Statistics Across Exchange Rate Regimes

Statistics[a]	Data[b]				Baseline Economy			
	Home		Foreign		Home		Foreign	
	Float[c]	Ratio[d]	Float[c]	Ratio[d]	Float	Ratio[d]	Float	Ratio[d]
Standard Deviations								
Y	1.73	1.10	1.84	0.99	1.08	1.13	1.12	0.86
C	1.33	1.30	1.7	1.35	1.35	1.17	1.46	1.27
I	5.55	1.42	4.37	0.91	4.40	0.89	4.48	1.13
H	1.42	1.21	2.37	1.34	0.68	1.30	0.65	0.8
NX	2.65	0.87	2.43	0.89	1.10	1.58	1.10	1.58
M	1.37	0.86	3.54	0.88	11.8	1.05	17.1	1.50
R	0.46	1.64	0.42	1.46	0.67	1.05	0.70	1.37
π	0.51	1.38	0.74	0.98	3.16	1.07	3.33	1.14
S	5.56	4.34	4.26	2.13	8.35	–	8.35	–
$S/\$$	–	–	7.55	3.36	–	–	–	–
Z	5.15	–	4.98	–	3.41	–	3.41	–
$Z/\$$	–	–	7.26	2.65	–	–	–	–

[a]Series are quarterly, logged (with exception of net exports and inflation) and passed through the HP filter.

[b]Data were taken from the IMF International Financial Statistics: Y is real GDP (industrial production for France); C is nominal total private consumption expenditures deflated using the GDP deflator (CPI for France); I is change in nominal stocks deflated using the GDP deflator; N is industrial employment; NX is net exports over total sum of imports and exports; π is quarterly CPI inflation; Z and S are real and nominal effective exchange rates computed by the IMF (REC and NEC, respectively); $e/\$$ and $z/\$$ are nominal and real exchange rates vis-á-vis the U.S. dollar (based on relative CPI). Home statistics refer to the US, foreign ones to averages of the other G7 countries.

[c]The Bretton Woods period is taken to run from 1957:1 to 1972:4 (or shorter subject to data availability); the Post-Bretton Woods from 1974:1-1997:4.

[d]Statistic value under a float over value under a peg.

Table 3
Ratios of Relative Prices' Second Moments
Across Exchange Rate Regimes

	$St.Dev.(q^*)$	$St.Dev.(q)$	$Cov(q^*, q)$
Fix vs. Float	1.15	1.08	1.98

Table 4
Sensitivity Analysis: LCP and Flexible Price Sector

Statistics[a]	Variations on Baseline Economy			
	No LCP[b]		Low γ[c]	
	Home	Ratio	Home	Ratio
Standard Deviations				
Y	1.00	0.99	1.11	1.08
C	1.19	1.03	1.31	1.10
I	4.42	0.86	3.72	0.86
H	0.58	1.25	0.58	1.30
NX	3.34	4.35	0.93	1.35
M	12.4	1.02	11.6	0.98
R	0.67	1.01	0.65	1.02
π	2.94	0.98	1.19	1.03
S	8.80		6.50	
Z	2.96	21.0	3.49	39.0

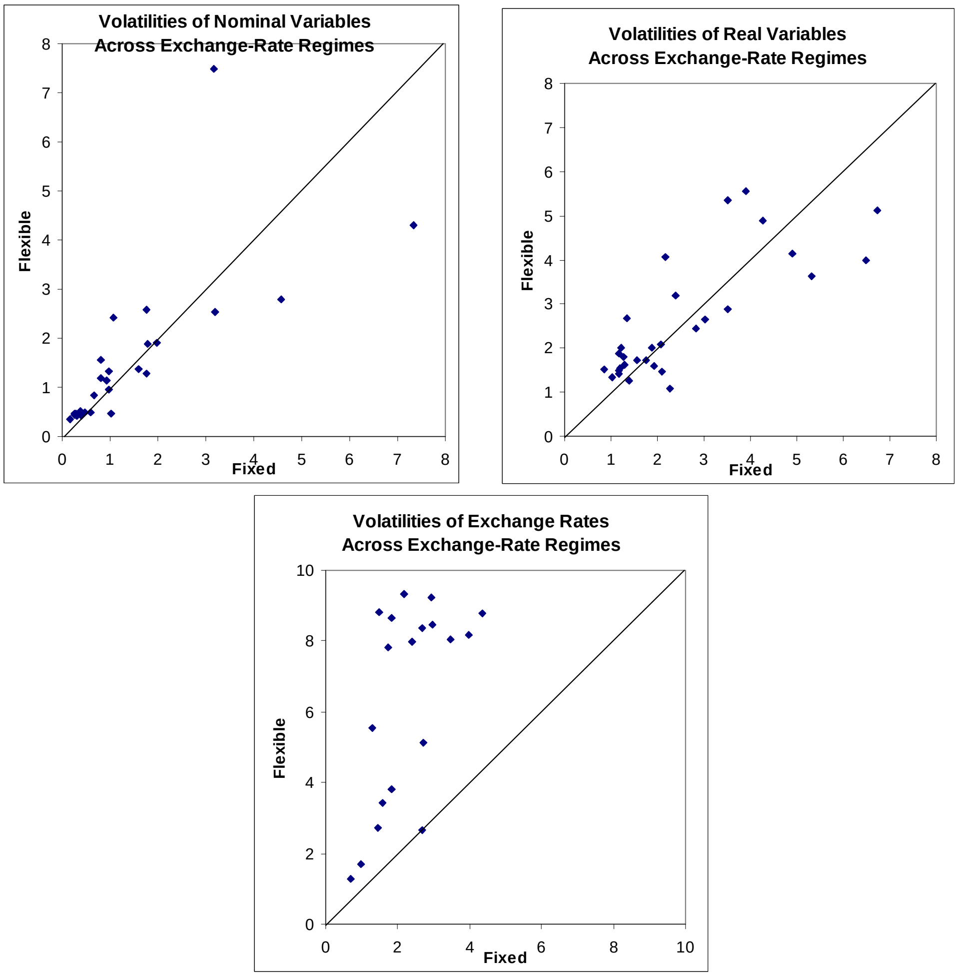
[a]All statistics are referred to the home country.
[b]Firms are assumed to set export prices in the home currency.
[c]The steady state consumption share of the homogeneous good is set to $\gamma = 0.01$.

Table 5
Sensitivity Analysis: Business Cycle Statistics Across Monetary Rules

Statistics[a]	Variations on Baseline Economy[b]					
	Exogenous Money		Contemporaneous		Two Rules	
	Float	Ratio[c]	Float	Ratio[c]	Float	Ratio[c]
Standard Deviations						
Y	1.10	0.99	1.11	1.06	1.08	0.93
C	0.60	1.09	0.65	1.09	1.35	0.78
I	2.30	0.95	2.58	0.90	4.39	0.75
H	0.56	0.98	0.54	1.19	0.68	0.85
NX	0.75	1.04	0.80	1.14	1.05	0.69
M	0.54	1.04	10.5	0.99	11.9	1.73
R	0.67	1.05	0.61	1.01	0.66	1.36
π	0.91	1.03	1.37	1.03	3.16	0.77
S	2.85	–	8.67	–	8.42	–
Z	1.45	–	1.67	–	3.43	–

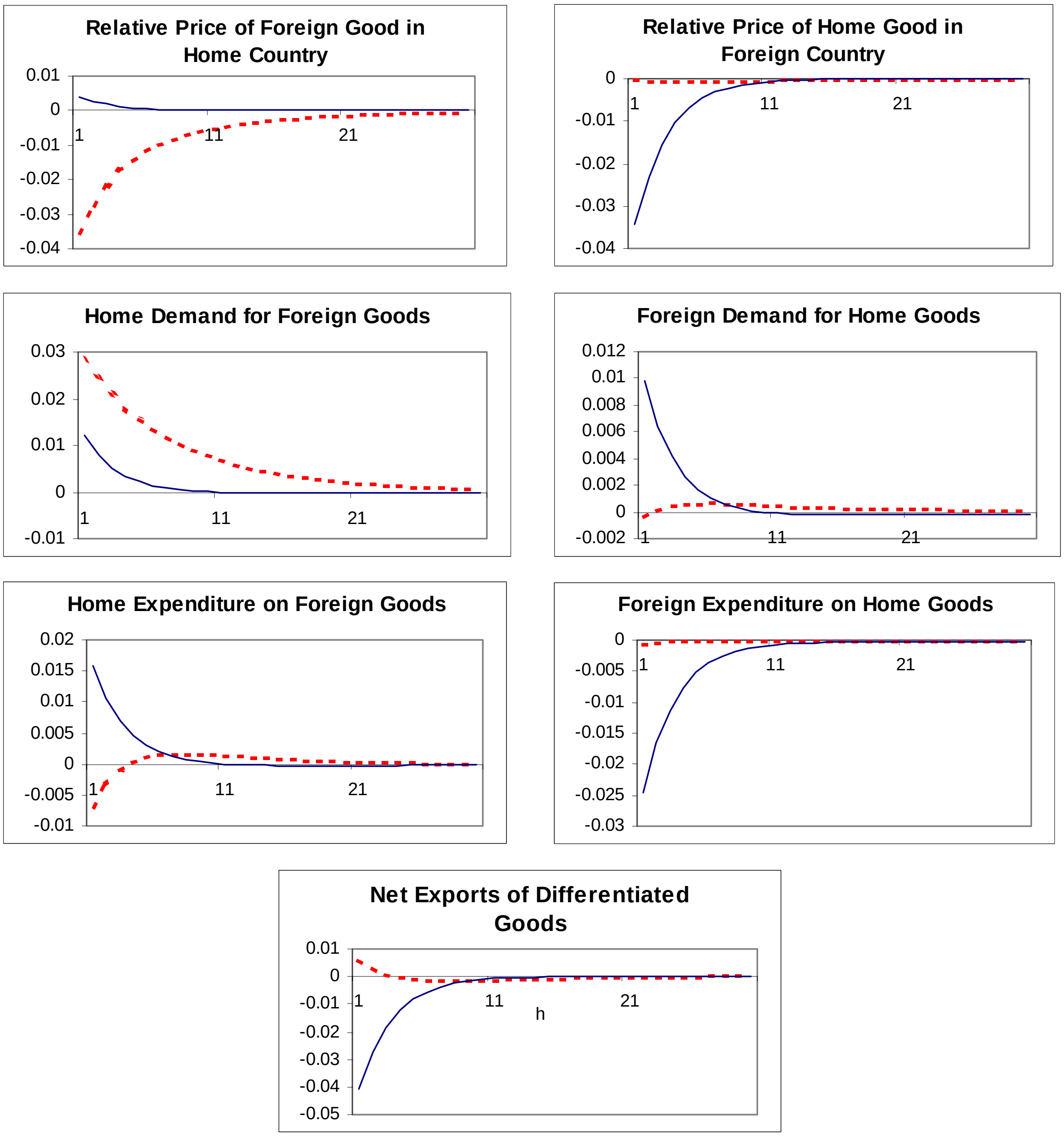
[a]All statistics are referred to the home country.
[b]See Section 5.2 for the experiments description.
[c]Statistic value under a float over value under a peg.

Figure 1: Volatilities of Real and Nominal Variables Under and After Bretton Woods



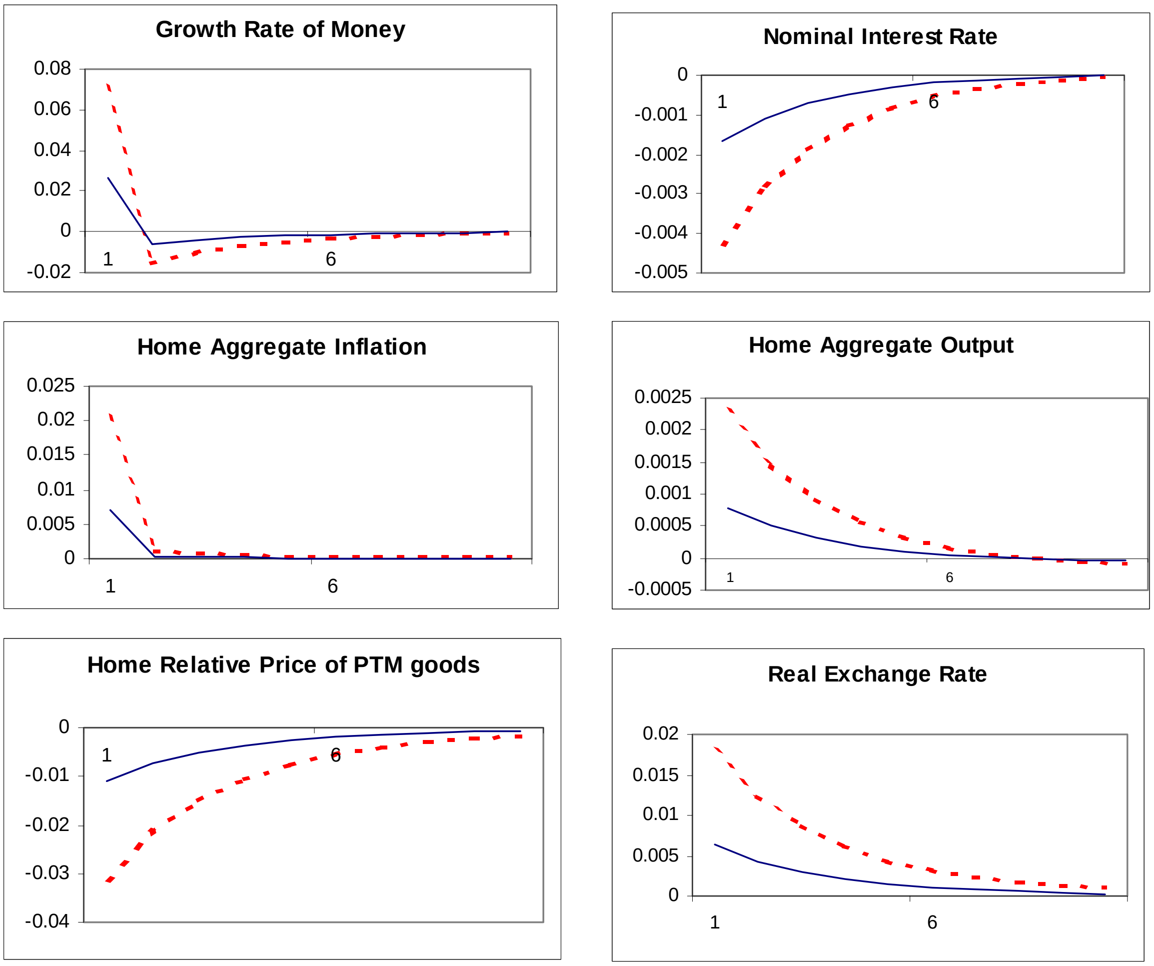
Countries are G7. Nominal and real variables are as defined in Table 2.

Figure 2. LCP Vs. No LCP



The solide line and dotted lines represent the reponses of the variable under no *LCP* and *LCP*, respectively, to a one-standard deviation monetary shock. The responses denote deviations from steady state.

Figure 3. Forward-Looking And Contemporaneous Rules



The solide line and dotted lines represent the reponses of the variable under the contemporaneous and forward-looking rules, respectively to a one-standard deviation monetary shock. The responses denote deviations from steady state.