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The exchange rate in a model of pricing-to-market

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Abstract

Much recent evidence suggests that exchange rate movements have very little effect on prices of traded goods. This paper presents some fresh evidence on this phenomenon, and develops a general equilibrium model consistent with the non-response of prices to exchange rate movements that are generated by money shocks. In the model some firms engage in pricing-to-market (PTM) across countries. The main question addressed is the degree to which PTM itself affects the behaviour of the exchange rate. It is shown that the presence of pricing-to-market combined with sticky local-currency nominal prices magnifies the response of the exchange rate to money shocks, and that the degree of exchange rate variability may be increased considerably relative to a model where the law of one price holds continuously.

JEL classification: F3; F4

Keywords: Pricing-to-market; Exchange rates; Purchasing power parity

1. Introduction

It is well known that real exchange rates exhibit large and persistent departures from purchasing power parity (PPP). The traditional explanation for this relies on the presence of non-traded goods. But accumulating evidence in the last decade

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has established that real exchange rate fluctuations are equally attributable to systematic failures of the law of one price among internationally traded goods. Since the mid-1980s, many studies have shown extensive pricing-to-market (PTM) in traded goods industries. That is, firms tend to set prices in local currencies of sale, and do not adjust prices to movements in the exchange rate. [1] More recently, Engel (1993), and Engel and Rogers (1994), show that for a wide range of commodities the deviation from the law of one price across international borders is far greater than can be explained by geographical distance or the costs of transportation. [2] A simple characterization of these findings would be that prices of most goods seem to exhibit 'local currency price stability' (i.e. prices are set in the currency of the buyers and do not adjust at high frequencies), while real exchange rate movements are driven primarily by fluctuations in the nominal exchange rate.

This paper first presents some evidence of local currency price stability in response to aggregate shocks which move the exchange rate. We then develop a very simple model of exchange rate determination in which local currency prices are sticky, and explore its implications for real exchange rate variability. There are two basic features underlying the model. The first is based on the hypothesis that for most categories of goods, trade is carried out by firms alone. Households cannot without significant cost directly arbitrage away price differences across countries. These costs include not just transportation or distribution costs, but also country-specific product warranties, difference in environmental regulations, product standardization, and so forth. Moreover, most international trade takes place in the form of differentiated goods in which individual firms tend to have monopoly power. Both factors allow firms to engage in international PTM, effectively segmenting markets country by country.

The second feature of the model is based on the hypothesis of nominal price-setting. In our environment, essentially a version of Obstfeld and Rogoff (1995) extended to allow for PTM, it is the combination of PTM and sticky prices that offers results of interest. Our evidence suggests that local CPI prices are sticky in response to money shocks, although the exchange rate responds significantly. When local currency prices are sticky, the presence of PTM has implications for exchange rate variability that diverge sharply from those generated either by a

[1] See for instance, Mann (1986), Krugman (1987), Giovannini (1988), Marston (1990), Knetter (1989) and Knetter (1993), among many others.

[2] Engel (1993) presents evidence that relative price variability of identical goods across international borders is far greater than that between differentiated goods within a single country, using disaggregated Canadian and US price data. Using disaggregated consumer good price series from a set of Canadian and US cities, Engel and Rogers (1994) show that deviations from the law of one price are far greater between cross-border cities at a given geographical distance than for within-country cities at the same distance.

flexible price model or by a sticky-price general equilibrium model in which PTM is absent.

There has been quite a large theoretical literature on PTM following the well-known contributions of Dornbusch (1987) and Krugman (1987). [3] Most of this is based on a partial equilibrium perspective. Taking the stochastic process for the exchange rate as given, the consequences of market segmentation for the pass-through from nominal exchange rates to prices is explored. But one of the main issues of interest is the implications of PTM for the exchange rate itself. Krugman (1989), for instance, argues that excessive real exchange rate volatility is itself generated by the weak response of international pricing and investment decisions to exchange rate movements.

We employ a model of differentiated products in which a subset of products are sold in markets where firms can price-discriminate across countries. In the presence of nominal price setting, unanticipated money shocks can have aggregate non-neutralities. When firms engage in PTM, country specific money shocks have very different effects than the more conventional exchange rate models in which prices are set in the currency of the seller. For instance, in the presence of a significant degree of PTM, an exchange rate depreciation has little effect on the relative price of imported goods facing domestic consumers. Thus, the allocative effects of exchange rate adjustment are weakened by PTM.

Is PTM responsible for a greater amplitude of real exchange rate movements? The simple model of this paper answers yes. With a large PTM sector, a money shock, generating a depreciation of the currency, does not tend to reallocate spending away from domestic goods consumption towards foreign goods. Because domestic prices show little response to a depreciation, the exchange rate response is magnified. A simple quantitative exercise based on the estimated degree of PTM in international trade shows that the increase in exchange rate variability arising from PTM may be very large.

2. Some evidence

We first present some evidence on the insensitivity of aggregate price levels to nominal exchange rate disturbances. In particular, we consider the effects of domestic monetary policy shocks for the domestic CPI, the CPI based real exchange rate of the domestic country, and the nominal exchange rate in monthly data on the G-7 countries from the flexible exchange rate era 1974:1–1994:12.

[3] Dixit (1989), Froot and Klemperer (1989), Giovannini (1988), Kasa (1992), Marston (1990) and Delgado (1991) present partial equilibrium analyses of PTM which can rationalize imperfect pass-through under certain industry level conditions.

Following Christiano and Eichenbaum (1992a,b) and Eichenbaum and Evans (1995), we identify exogenous domestic monetary policy shocks with orthogonalized innovations to Non-Borrowed Reserves in the US. Specifically, they are identified as the orthogonal disturbance to Non-Borrowed Reserves from a vector autoregression in which the following Wold-ordering of seven variables is imposed; US output as measured by industrial production (Y), the US price level measured by the CPI (P), foreign country industrial production (Y^*), the foreign country's interest rate (R^*), US Non-Borrowed Reserves, the US interest rate (R), and the real CPI or nominal exchange rate – $x = eP^*/P$ or e – between the $US and foreign country's currency, where e is the foreign country price of one $US. [4]

The results that we obtain when Japanese and German data are employed to represent foreign country variables are displayed in Figs. 1 and 2 respectively, and similar results are generated by each of the six bilateral country pairs that we study. It is evident that positive innovations to monetary policy cause sharp and persistent depreciations of the real and nominal exchange rate of the $US, depreciations that are quantitatively very similar, suggesting that the response of the CPI ratio is very limited. Furthermore, Fig. 1c and 2c directly show that the domestic (US) CPI response is flat and barely significant at any lag, by contrast to the highly volatile exchange rate responses exhibited in Fig. 1a and 2a. Thus, while the conditional correlations reported here suggest that monetary policy shocks cause large and significant movements in the nominal exchange rate, these are not reflected in similar CPI movements or, by implication, in import price indices.

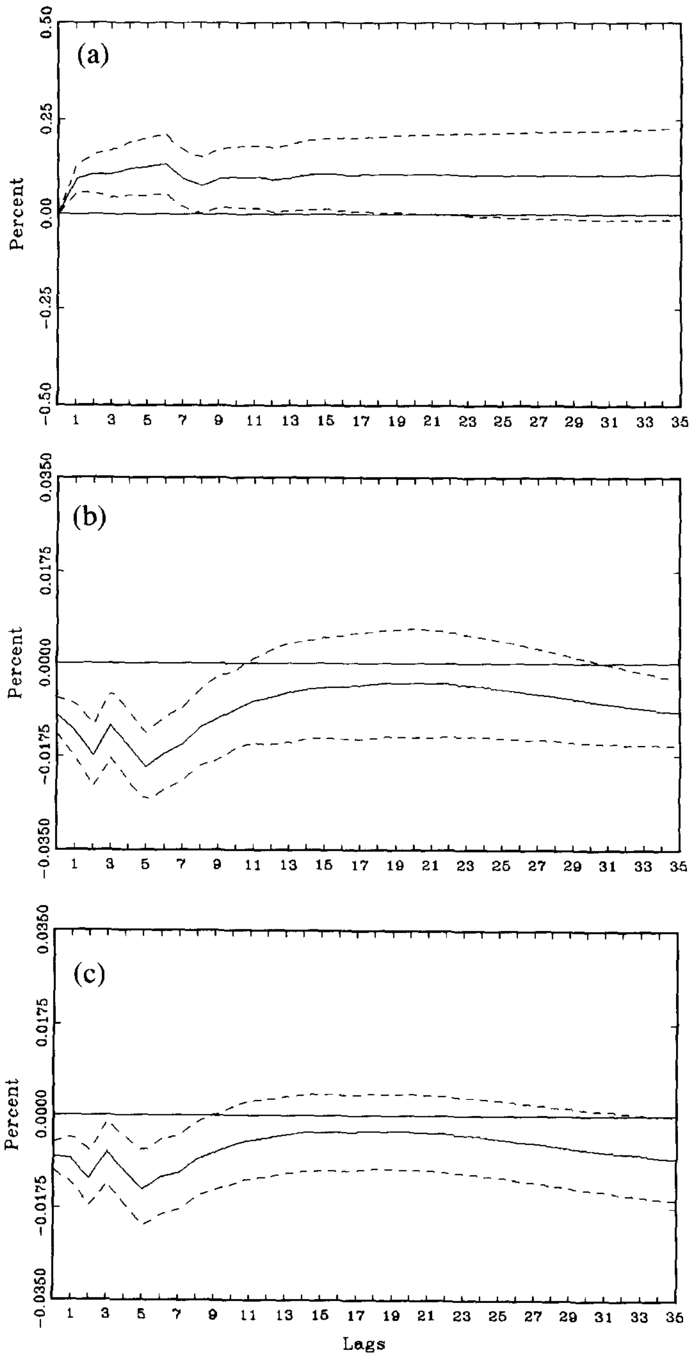
3. The model

What aggregate implications does PTM have? In this section we present a simple model to address this question. The model is first presented under the assumption of fully flexible nominal prices. In this case, PTM has no aggregate implications at all, for any kinds of shocks. But with nominal price stickiness, we find implications of PTM that differ considerably from PPP based models.

The structure is essentially a version of Obstfeld and Rogoff (1995) extended to allow for PTM. Let there be two countries in a world economy. We denote the foreign country variables with an asterisk. Households supply labour and consume

[4] This Wold decomposition is essentially that studied by Eichenbaum and Evans (1995). Here, all output and price data is drawn from the IMF International Financial Statistics data base, while the Federal Reserve database is the source for Non-Borrowed Reserves, domestic and foreign interest rates, which are measured by various short-term rates.

Fig. 1. a: US CPI response to US money shock. b: Nominal DM/$US exchange rate. c: Real DM/$US exchange rate.


(a)
0.50
0.25
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Percent
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35
(b)
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-0.0350
Percent
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35
(c)
0.0350
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1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35
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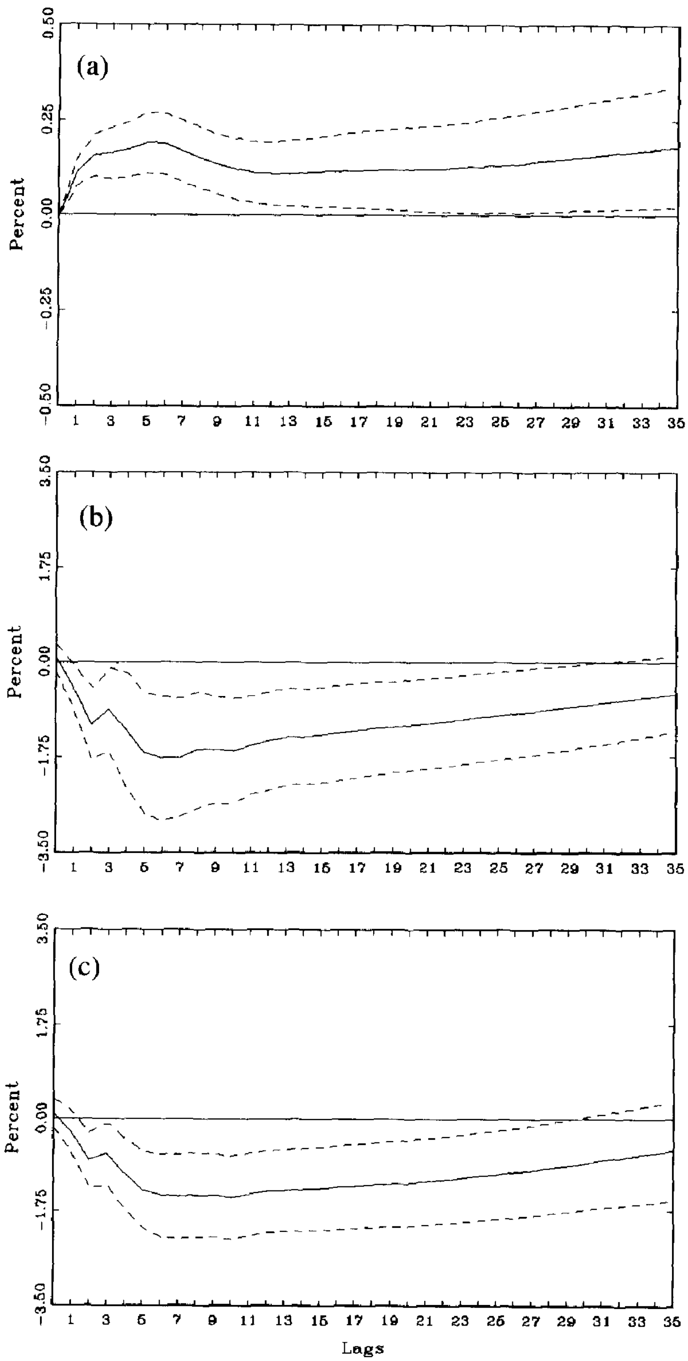
(a)
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0.25
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a group of differentiated goods of total measure unity. Of these goods a fraction n are produced by the home country, and $1-n$ are produced in the foreign country. We also let n and $1-n$ represent the population of the home and foreign country, respectively.

Each good is sold exclusively by a price-setting firm. A fraction s of firms in each country can price-discriminate across countries. We denote these as PTM goods. The PTM firms set prices separately for the home and the foreign market, since by assumption, only firms can trade these goods. Consumers cannot trade PTM goods directly across countries. The other $1-s$ goods can be freely traded by consumers, so that firms must set a unified price across the two countries.

3.1. Households

Let agents in the home economy have preferences over consumption given by [5]

$$U=\left(\log C+\frac{\gamma}{1-\epsilon}\left(\frac{M}{P}\right)^{1-\epsilon}+\eta\log(1-h)\right),$$

where $C=(\int_0^1 c(i)^{(\rho-1)/\rho}\mathrm{d}i)^{\rho/(\rho-1)}$ $(\rho>1)$. There is a fixed unit measure of differentiated goods, where $c(i)$ is the consumption of good i. h represents total hours worked by the domestic household. Households also value real money balances M/P, where M are nominal balances and P is the home country CPI, defined as

$$P=\left[\int_0^n p(i)^{1-\rho}\mathrm{d}i+\int_n^{n+(1-n)s}p^*(i)^{1-\rho}\mathrm{d}i\right.$$
$$\left.+\int_{n+(1-n)s}^1(eq^*(i))^{1-\rho}\mathrm{d}i\right]^{1/(1-\rho)}.$$

Let prices denoted p represent home currency prices, while prices denoted q represent foreign currency prices. Here $p(i)$ is the home currency price of the home-produced good, $p^*(i)$ is the home currency price of a foreign PTM good i, while $q^*(i)$ is the foreign currency price of a foreign non-PTM good. The exchange rate is given by e.

Households receive income from wages, Wh, profits on their ownership of domestic firms π, and transfers TR from government. Their budget constraint is

$$PC+M=Wh+\pi+M_0+TR, \tag{1}$$

where M_0 is the money holding at the beginning of the period.

[5] To illustrate the most basic aggregate implications of PTM for exchange rates, we develop a one period model in this paper. For the more general case see Betts and Devereux (1995).

Fig. 2. a: US CPI response to US money shock. b: Nominal Yen/$US exchange rate. c: Real Yen/$ exchange rate.

The household optimally allocates consumption between each of the differentiated goods as follows:

$$c(i)=\left(\frac{v(i)}{P}\right)^{-\rho}C, \tag{2}$$

where $v(i)$ is equal to either $p(i)$, $p^*(i)$, or $eq^*(i)$, depending upon which category the good i falls within.

In addition, the household's optimal money demand and labour supply decisions can be described as

$$\frac{M}{P}=(\gamma C)^{1/\epsilon}, \tag{3}$$

$$\frac{\eta}{1-h}=\frac{W}{PC}. \tag{4}$$

The situation of foreign households is entirely analogous.

3.2. Firms

There are two types of firms; firms who may price-to-market, and firms who must set a unified international price. Take a home firm i. The firm operates a simple linear technology $y(i)=Ah(i)$, where $y(i)$ is total output of the firm, $h(i)$ is employment, and A is a constant. For PTM firms, let total output be divided between output sold domestically, given by $x(i)$, and output sold abroad, given by $z(i)$.

The firm hires labour domestically and chooses $p(i)$ and $q(i)$, the nominal prices in the home and foreign market, respectively. Profits of the PTM firm are given by $\pi(i)=p(i)x(i)+eq(i)z(i)-(W/A)(x(i)+z(i))$. The firm sets $p(i)$ and $q(i)$ separately to maximize profits. It faces the demand schedule given by (2) and an analogous schedule for the foreign consumer. The firm will choose to set prices in the two markets as a markup over marginal cost such that

$$p(i)=eq(i)=\frac{\rho}{\rho-1}\frac{W}{A}. \tag{5}$$

Since elasticities of demand are the same in each market here, the law of one price must hold even for PTM goods, in the flexible price case.

The foreign PTM firm's pricing policy is described analogously, so that, for the foreign firm i, $p(i)^*=eq(i)^*$. It follows that PPP must hold with flexible prices, so that $eP^*=P$. It is then immediate that for the non-PTM firm, total world demand is given by $(p(i)/P)^{-\rho}(C+C^*)$, and the optimal price–wage markup will be the same as (5).

3.3. Government

The government prints currency in order to finance transfers to households. The home country government budget constraint is then

$$PG + TR = M - M_0. \tag{6}$$

4. Exchange rate variability with pricing to market

4.1. Flexible prices

With flexible prices, the world market for each good must clear, labour supply must equal labour demand for each country, and money market equilibrium must hold in each country also. Equilibrium values for employment, consumption, and the exchange rate, are given by

$$h = h^* = \frac{(\rho - 1)/\rho}{((\rho - 1)/\rho) + \eta}, \tag{7}$$

$$C = \frac{p}{P} Ah = Ah, \tag{8}$$

$$C^* = Ah^*, \tag{9}$$

$$e = \frac{M}{M^*}\left(\frac{C^*}{C}\right)^{1/\epsilon}. \tag{10}$$

The degree of PTM has no implications at all, for the flexible-price economy. This is true for not just for money shocks, but for any types of shocks.

4.2. Sticky prices

Now assume that prices are set in advance and cannot respond to shocks within the period. Firms must respond to demand shocks by meeting market demand at the pre-set price. In the sticky price environment, we may describe an equilibrium by the following equations:

$$\frac{M}{P} = (\gamma C)^{1/\epsilon}, \tag{11}$$

$$\frac{M^*}{P^*} = (\gamma C^*)^{1/\epsilon}, \tag{12}$$

$$PC = n(1 - s) py + ns(px + eqz), \tag{13}$$

$$P^* C^* = (1-n)(1-s) p^* y^* + (1-n) s\left(\frac{p^*}{e} x^* + q^* z^*\right), \tag{14}$$

$$y = \left(\frac{p}{P}\right)^{-\rho} nC + \left(\frac{p}{eP^*}\right)^{-\rho} (1-n) C^*, \tag{15}$$

$$y^* = \left(\frac{eq^*}{P}\right)^{-\rho} nC + \left(\frac{q^*}{P^*}\right)^{-\rho} (1-n) C^*, \tag{16}$$

$$x = \left(\frac{p}{P}\right)^{-\rho} nC, \tag{17}$$

$$z = \left(\frac{q}{P^*}\right)^{-\rho} (1-n) C^*, \tag{18}$$

$$x^* = \left(\frac{p^*}{P}\right)^{-\rho} nC, \tag{19}$$

$$z^* = \left(\frac{q^*}{P^*}\right)^{-\rho} (1-n) C^*. \tag{20}$$

Eqs. (11) and (12) are just the money market clearing conditions. Eqs. (13) and (14) are the national budget constraints (or balance of payments equations). In particular (13) says that domestic nominal consumption must equal nominal income from non-PTM firms $n(1-s)py$, plus nominal income from PTM firms $ns(px + eqz)$, where x and z, respectively, represent sales in the home and foreign markets. Eq. (14) has a similar interpretation. Finally, Eqs. (15)–(20) represent goods market clearing equations, for home and foreign non-PTM firms, and for home and foreign PTM firms in both home and foreign markets, respectively.

For given nominal prices, the system (11)–(20), along with the definitions of P and P^*, give ten equations in the nine unknowns $\{C, C^*, e, y, y^*, x, x^*, z, z^*\}$. One equation is redundant by Walras' law. We solve the system by linear approximation around the initial, zero-shock equilibrium. For any variable U, let $\hat{U} = (U - \overline{U})/\overline{U}\}$, where $\overline{U}$ is the zero-shock equilibrium value.

First, from the definitions of the price indices, P and P^*, it is easy to show that

$$\hat{P} = (1-n)(1-s)\hat{e}, \tag{21}$$

$$\hat{P}^* = -n(1-s)\hat{e}. \tag{22}$$

With sticky prices, the response of aggregate price indices to an exchange rate depreciation is lower, the greater the share of goods subject that is subject to PTM. As $s \to 1$, P and P^* are entirely unaffected by an exchange rate depreciation.

4.3. Response of the exchange rate

Using (21) and (22), and the money market clearing equations (11) and (12), the movement of the exchange rate can be written

$$\hat{e}(1-s)=\hat{M}-\hat{M}^*-\frac{1}{\epsilon}(\hat{C}-\hat{C}^*). \tag{23}$$

This represents the fundamental exchange rate equation common to the standard monetary approach. The exchange rate will depreciate in response to relative national money growth, and will appreciate in response to relative national growth in real consumption. The term $(1-s)$ enters on the right-hand side of this equation due to the fact that the size of s determines the magnitude of the departure from PPP.

Now taking a linear approximation of (13) and (14), using (15)–(20), and subtracting, we arrive at

$$\hat{e}=\frac{\hat{C}-\hat{C}^*}{(1-s)(\rho-1)+s}. \tag{24}$$

To see the intuition behind (24), take the differential impact of an arbitrary exchange rate depreciation on home and foreign households. When $s=0$, an exchange rate deprecation causes a rise in the relative price of foreign goods facing both home and foreign households. World demand shifts towards the home country, leading to an increase in production, income and therefore consumption in the home country, relative to the foreign country. The increase in domestic relative to foreign consumption is proportional to the reallocation of world demand, which is determined by the magnitude of $\rho-1$.

Alternatively, take instead the case of an exchange rate depreciation under complete PTM ($s=1$). Relative prices facing households in both countries remain unaffected by this. However, relative incomes are affected. A depreciation raises the home currency earnings of home firms, and reduces the foreign currency earnings of foreign firms, at given production levels. Thus a depreciation generates an income redistribution which favours the domestic country, thus raising domestic relative to foreign consumption.

Combining (23) and (24), we arrive at the solution for the exchange rate:

$$\hat{e}=\frac{\epsilon(\hat{M}-\hat{M}^*)}{(1-s)(\epsilon+\rho-1)+s}. \tag{25}$$

How does PTM affect the response of the exchange rate? From (25), it can be seen that a rise in s will increase the response of the exchange rate so long as

$$\epsilon>2-\rho.$$

Since $\rho > 1$, this condition says that the presence of PTM will increase the volatility of the exchange rate so long as the consumption elasticity of money demand is not too high. An elasticity of unity or less is sufficient, but not necessary, to satisfy this condition. In fact, since reasonable estimates (see below) suggest that $\rho > 2$, this condition is likely to be satisfied for any value of ϵ. If, in addition, the consumption elasticity of money demand is below unity, then in addition to increasing exchange rate volatility, the presence of PTM can generate exchange rate 'overshooting' [6] in response to money shocks.

Thus, the model can capture the intuition that PTM not only allows for deviations from the law of one price at the level of individual commodities, but at the aggregate level, generates increased exchange rate volatility. In the conventional model an exchange rate depreciation generates an immediate relative price change. The reallocation of world demand tends to mitigate the relative price movement, and therefore reduce the response of the exchange rate. In the PTM world, there is no such relative price change. An exchange rate depreciation simply generates an income redistribution which raises home income relative to foreign income and raises demand of home consumers for home and foreign goods alike. Thus, there is no mitigating reallocation of demand away from foreign goods.

From (25), notice that as $s \to 1$, the exchange rate plays a smaller and smaller role in the relative money market equilibrium condition. When $s = 1$, PPP fails entirely, and the fundamental monetary equation plays no direct role in determining the exchange rate. The system then becomes recursive, where relative consumption growth is determined by (23) and the exchange rate in turn is determined by (23) and (24).

Nominal exchange rate depreciation is coincident with real depreciation, so long as there is some PTM. From (21) and (22) above, the response of the real exchange rate to a depreciation is

$$\hat{P}^* + \hat{e} - \hat{P} = s\hat{e}.$$

In the economy without PTM, there is no real exchange rate volatility at all. The law of one price holds continually. But as $s \to 1$, real exchange rate variability translates directly into deviations from the law of one price, and the response of the real and nominal exchange rates become identical.

4.4. Exchange rate volatility

What is the quantitative implication of PTM for exchange rate volatility? To explore this, we ask the question; how much does PTM contribute to the volatility

[6] It is somewhat misleading to refer to exchange rate 'overshooting' in a one-period model. Nevertheless, if a money shock causes the exchange rate to rise by more than it would in the flexible-price economy, one may think of this as a type of overshooting.

Table 1

s	0	0.25	0.45	0.65	0.85	1
Variance	0.16	0.21	0.27	0.36	0.57	1

of the exchange rate relative to an economy where the law of one price continuously holds for all goods?

Three parameters determine this comparison; the elasticity of demand for consumption goods ρ, the consumption elasticity of demand for money $1/\epsilon$, and the share of goods subject to PTM, s. The first parameter can be derived from the empirical estimates of markups. Rotemberg and Woodford (1993) argue for a markup of 1.2 in US data. In our model the markup is $\rho/(\rho-1)$. This implies a value of $\rho=6$. An estimate of the consumption elasticity of the demand for money equal to unity is reported by Mankiw and Summers (1986). This implies that $\epsilon=1$. Finally, Knetter (1993) reports estimates of the proportion of industries that are subject to 'local currency price stability', by country. This is essentially equivalent to PTM in our model. His point estimates differ across countries. The highest estimate is Germany, with 89 percent of industries subject to PTM, while the lowest is for the US, with 45 percent. Not all of these estimates are significant, however. In order to take a very conservative approach, we take $s=0.45$, the lowest point estimate. [7] Table 1 illustrates the impact of PTM on exchange rate volatility. The table reports the value of $\psi=\sigma_e^2/\sigma_D^2$, where $D=M-M^*$.

With a value of $s=0.45$, the variance of the exchange rate is almost three times higher than in an economy where the law of one price holds continuously. As s increases, the relative variance grows even larger. Thus, in this model, the presence of PTM has a dramatic impact on exchange rate volatility.

These estimates are simply illustrative. For a more robust calculation one would need to develop a full-blown intertemporal dynamic model. However, the size of the increase in υ is suggestive of the importance of PTM in the determination of exchange rate volatility.

5. Conclusions

This short paper simply sketches out some of the implications of pricing-to-market for exchange rate variability. Our simple model captures well the notion that exchange rate variability may have few direct consequences for nominal

[7] There is some imprecision here due to the fact that the industries in Knetter's study are of different sizes, whereas our symmetric equilibrium requires industries to be of identical size. It is not really clear in what direction this would bias the estimates, however. The figure of 0.45 is also consistent with results of the other studies mentioned in the introduction.

prices facing households. In the aggregate, this may magnify exchange rate variability itself. A fuller analysis of the aggregate role of PTM would require us to develop a more complete dynamic model however.

6. For further reading

Krugman (1989), Rogers and Jenkins (1994).

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