The Manchester School Supplement 2002
1463–6786 1–15

THE RESPONSIVENESS OF CONSUMER PRICES TO EXCHANGE RATES: A SYNTHESIS OF SOME NEW OPEN ECONOMY MACRO MODELS

by
*CHARLES ENGEL**
University of Wisconsin and NBER

General equilibrium optimizing models with sticky nominal prices allow us to revisit questions about optimal monetary policy in open economies. If nominal prices are set in producers' currencies, appropriate monetary policy can reproduce the allocations under flexible prices. If nominal prices are set in consumers' currencies, stable nominal exchange rates may be desirable. In this case, a nominal exchange rate fixed at the purchasing power parity level can have desirable consequences for risk sharing, and nominal exchange rate flexibility cannot deliver optimal relative price changes. However, evidence shows that pass-through may be greater to import prices than to consumer prices. If prices are fixed for consumers, but importer-distributors face pass-through, then monetary policy-makers face a trade-off that might require some control of nominal exchange rates, but not purely fixed rates.

1 Introduction

The 'new open economy macroeconomics' is an exciting new development that revives Keynesian IS–LM style analysis, but within a framework of optimizing agents. The literature has the advantage that policy recommendations can be based explicitly on a criterion of maximum household welfare, instead of some *ad hoc* criterion. This new literature has some interesting initial results on optimal policy and exchange rate flexibility.

I will examine some new open economy macroeconomic models under three separate assumptions about how nominal prices are set. In all cases, there are some nominal prices that I assume are set for one period. I shall examine static versions of the models, since I will be able to discuss the relevant issues in that simplified framework.

I will first construct the model under nominal price flexibility, and then compare that model to the sticky price models. In the first sticky price model, prices are set in the currency of the producer. (This is the PCP model, for 'producer-currency pricing'.) This means that there is full pass-through of nominal exchange rate changes to consumer prices. That is,

* This paper was prepared for the Money, Macro and Finance annual conference in Belfast, Northern Ireland, September 2001. The National Science Foundation has supported this research through a grant to the University of Wisconsin—Madison.

Published by Blackwell Publishers Ltd, 108 Cowley Road, Oxford OX4 1JF, UK, and 350 Main Street, Malden, MA 02148, USA.

the price in the home country of a foreign good moves one-for-one with changes in the nominal exchange rate. In this framework, changes in the nominal exchange rate translate into changes in the relative price of home-produced to foreign-produced goods. As the nominal exchange rate changes, consumers' demand for home relative to foreign goods is altered.

The second model is one in which the home and foreign markets are segmented, and firms set two different prices—one in domestic currency for home consumers, and one in foreign currency for foreign consumers. There is a body of empirical evidence to suggest that consumer prices are not very responsive to exchange rate changes, so this pricing assumption is consistent with that evidence.[1] This model is labeled the LCP model (for 'local-currency pricing'.) In this model, changes in the nominal exchange rate have no short-run effect on prices faced by consumers, and thus have no influence on the relative demand for home versus foreign goods.

However, while consumer prices are not very responsive to exchange rate changes, there appears to be more pass-through of exchange rate changes to imported good prices. That is, there is a distinction between import prices and consumer prices, which presumably is related to the role of distributors in the economy.[2] So, the third model has a (competitive) distribution sector that imports goods and then sells them to consumers. Final prices are set in the consumers' currencies, but the opposite assumption is made about import prices—that there is full pass-through. Because exchange rate changes affect prices faced by distributors, they affect the distributors' relative demands for home and foreign goods. But nominal exchange rate movements still have no effect on consumer demand.

The literature (Obstfeld and Rogoff, 2000, 2002) has shown that in the PCP setting it is not desirable for monetary policy to target exchange rates. An appropriate monetary policy can replicate the allocations under flexible exchange rates, and the optimal policy can be achieved without any coordination between monetary authorities. In contrast, Devereux and Engel (2001) have shown that, under the LCP setting, fixing nominal exchange rates is the outcome of optimal monetary policy. I review these arguments below in the context of a general model that can allow for different assumptions on pricing. I then argue that the third model—which is perhaps the most plausible empirically—has intermediate implications for exchange rate targeting. It is desirable to have less exchange rate

[1]See, for example, Engel (1993, 1999, 2000), Engel and Rogers (1996, 2001), Rogers and Jenkins (1995), Obstfeld and Taylor (1997) and Parsley and Wei (2001a, 2001b). Mussa's (1986) classic paper stimulated much of this research.

[2]See Goldberg and Knetter (1997) and Obstfeld and Rogoff (2000) for some evidence on this point.

flexibility than under PCP, but fixed exchange rates would not be optimal either.

These models are fully integrated equilibrium models in which households and firms make optimal choices but in which some nominal prices are not completely responsive to shocks. I will work with a simplified framework in which I can embed all of the approaches I want to discuss. Section 2 lays out the general model. Section 3 finds the solutions under flexible goods prices. Section 4 investigates the PCP case, and Section 5 the LCP case. In Section 6, I lay out the model with distributors. Section 7 concludes.

2 The General Model

There are two countries in the general model. I will assume that there is a single period, though most of the results I discuss carry over to a multi-period framework. I assume households in the home country maximize

$$U = \frac{1}{1-\rho} C^{1-\rho} + \chi \ln\left(\frac{M^{\mathrm{D}}}{P}\right) - \eta L$$

C is a consumption aggregate.

Households consume goods produced in the home country and in the foreign country. I will assume that aggregate consumption is a constant elasticity of substitution (CES) function of home and foreign consumption aggregates:

$$C = \left[\alpha^{1/\lambda} C_{\mathrm{H}}^{(\lambda-1)/\lambda} + (1-\alpha)^{1/\lambda} C_{\mathrm{F}}^{(\lambda-1)/\lambda}\right]^{\lambda/(\lambda-1)} \tag{1}$$

Here, λ is the elasticity of substitution between the home and foreign aggregates. C_{H} is an aggregator of consumption of goods produced in the home country, and C_{F} is likewise for goods produced in the foreign country. We assume that there is a continuum of such goods in each country. The consumption function for each of these subindices of consumption is also CES, with an elasticity of substitution (possibly) different from λ.

Real balances M^{D}/P appear in the utility function, where P is the optimal price index given by

$$P = \left[\alpha P_{\mathrm{H}}^{1-\lambda} + (1-\alpha) P_{\mathrm{F}}^{1-\lambda}\right]^{1/(1-\lambda)} \tag{2}$$

Households get disutility from work, L. η is a shock to disutility of work.

Foreign households are assumed to have similar utility functions:

$$U^* = \frac{1}{1-\rho} C^{*1-\rho} + \chi \ln\left(\frac{M^{*\mathrm{D}}}{P^*}\right) - \eta^* L^*$$

Starred (*) variables are the foreign household counterparts to the home country variables.

Money is supplied exogenously through transfers. In equilibrium we have money supply equals money demand in each country: $M = M^{\mathrm{D}}$ and $M^* = M^{*\mathrm{D}}$. Four variables will determine the aggregate state of the economy: the distaste for work for the representative home agent, η; the analogous variable for the representative foreign agent, η^*; aggregate per capita home money supply, M; and aggregate per capita foreign money supply, M^*.

I will assume there are complete financial markets of the type discussed in Devereux and Engel (2001). Specifically, there are assets traded that have payoffs specific to each possible state of the world. These assets are traded, of course, prior to the realization of the state. Most of the models we consider have home and foreign consumers facing different prices for the same good on spot markets. That is, the markets are segmented. We assume that it is impossible to make state-contingent trades that allow payoffs in physical goods, as that would allow households to get around paying the price set in their market. Instead, payoffs are specified in nominal terms. In that case, optimal contracts ensure that the marginal utility from an additional unit of currency is proportional between home and foreign consumers in all states (where I have assumed the constant of proportionality is one):

$$\frac{C^{-\rho}}{P} = \frac{C^{*-\rho}}{SP^*} \tag{3}$$

S is the nominal exchange rate, expressed as the home currency price of foreign currency.

The assumption of complete markets is, of course, unrealistic. It is a useful benchmark, and here it allows us to arrive at a simple flexible model that can be used to analyze relative price effects in general equilibrium. We can show that nominal exchange rate flexibility allows desirable relative price adjustments to occur rapidly under the assumption of nominal prices fixed in producers' currencies, but we can also analyze other assumptions about how prices are set.

The following equilibrium conditions emerge using the first-order conditions for the household optimization problem:

$$M = \chi P C^{\rho} \qquad M^* = \chi P^* C^{*\rho} \tag{4}$$

$$W = \eta P C^{\rho} \qquad W^* = \eta^* P^* C^{*\rho} \tag{5}$$

Here, W and W^* are the home and foreign wage, respectively.

Also, demands for home and foreign goods (by home consumers—foreign consumption demands are identical as functions of foreign prices and consumption) are given by

$$C_{\mathrm{H}} = \alpha^{\lambda}\left(\frac{P}{P_{\mathrm{H}}}\right)^{\lambda} C \qquad C_{\mathrm{F}} = (1-\alpha)^{\lambda}\left(\frac{P}{P_{\mathrm{F}}}\right)^{\lambda} C \tag{6}$$

The solution for the nominal exchange rate does not depend on any assumptions about the production side of the economy, or about how nominal prices are set:

$$S = \frac{M}{M^*} \tag{7}$$

Now we turn to the production side of the economy. There is a continuum of goods produced in each country, each by a monopolist (who faces a constant elasticity of demand, given our CES assumption on preferences). Output for each firm i is produced using only a labor input: $Y_i = L_i$ and $Y_i^* = L_i^*$.

With a population of $\frac{1}{2}$ in each country, we have employment given by

$$L = \tfrac{1}{2}C_{\mathrm{H}} + \tfrac{1}{2}C_{\mathrm{H}}^* \qquad L^* = \tfrac{1}{2}C_{\mathrm{F}} + \tfrac{1}{2}C_{\mathrm{F}}^* \tag{8}$$

We now examine this general model under various assumptions about price setting.

3 Flexible Nominal Prices

First is the case of completely flexible nominal goods prices. Since firms face constant elasticity demand curves, they set prices as a constant mark-up over wages. We allow firms to discriminate across home and foreign markets. But because we assume identical preferences and CES utility, firms choose to set the same price in both markets.

Aggregating across all home firms, we get

$$P_{\mathrm{H}} = \mu W \tag{9}$$

where P_{H} is the home currency price of home goods. We have also $P_{\mathrm{H}} = SP_{\mathrm{H}}^*$, where P_{H}^* is the foreign currency price of home goods. Likewise,

$$P_{\mathrm{F}}^* = \mu W^* \tag{10}$$

and $P_{\mathrm{F}} = SP_{\mathrm{F}}^*$. μ (>1) represents the mark-up.

We can also derive these equations for nominal wages in equilibrium:

$$W = \frac{\eta}{\chi}M \qquad W^* = \frac{\eta^*}{\chi}M^* \tag{11}$$

It follows from the equilibrium conditions (4) and (5) that

$$\frac{P_{\mathrm{H}}}{P_{\mathrm{F}}} = \frac{P_{\mathrm{H}}^*}{P_{\mathrm{F}}^*} = \frac{\eta}{\eta^*} \tag{12}$$

The relative price of home goods falls when there is an increase in η, which is the parameter measuring the distaste for work. When home households prefer to work less, home firms must pay higher wages to entice workers into the workforce. Those wage costs are passed on to the consumer in the form of higher prices.

Substituting the solutions for prices, (9) and (10), into the price index definition (2), we get

$$P = \frac{\mu M}{\chi}\left[\alpha\eta^{1-\lambda} + (1-\alpha)\eta^{*1-\lambda}\right]^{1/(1-\lambda)} \tag{13}$$

From the money market equilibrium condition and using equation (13), we can derive the expression for equilibrium consumption:

$$C = \mu^{-1/\rho}\left[\alpha\eta^{1-\lambda} + (1-\alpha)\eta^{*1-\lambda}\right]^{-1/\rho(1-\lambda)} \tag{14}$$

Because purchasing power parity holds in this model, $P = SP^*$, we know from the risk-sharing condition (3) that home and foreign consumption will be identical: $C = C^*$. Labor supply shocks (both home and foreign) have identical effects on home and foreign consumption.

The equilibrium levels of employment in each country depend on the relative shocks. Since consumption demands are identical in each country, employment is given by

$$L = C_{\mathrm{H}} \qquad L^* = C_{\mathrm{F}}$$

Using the demand functions (6), we derive

$$L = \alpha^{\lambda}\left[\alpha + (1-\alpha)\left(\frac{\eta^*}{\eta}\right)^{1-\lambda}\right]^{1/(1-\lambda)} \tag{15}$$

$$L^* = (1-\alpha)^{\lambda}\left[1 - \alpha + \alpha\left(\frac{\eta}{\eta^*}\right)^{1-\lambda}\right]^{1/(1-\lambda)} \tag{16}$$

The supply shocks affect employment differentially across the home and foreign country.[3]

[3]Of course, we want to assume that the labor supply shocks are genuine shocks, not somehow under the control of the household, and that the shocks are verifiable. That is because households buy and sell bonds that are contingent on the realization of the shocks, so they have the incentive to claim a positive shock to the disutility of work. As equations (14), (15) and (16) show, if home residents could claim falsely such a positive shock, their work levels would fall, foreigners' work levels would increase, and foreigners would share the burden of lost consumption.

4 Sticky Nominal Prices: PCP Case

Next is a model where firms must set nominal prices in advance—prices are set in advance of knowledge of the preference shocks and money supply realizations. First we take up the case in which firms set prices in their own currencies. That is, home firms set prices in the home currency, whether for sale to home or foreign households. This is the PCP model.

Because of identical preferences of home and foreign households, firms do not set a different price for home and foreign households (even though, in principle, we allow for price discrimination). That is, the law of one price holds for goods sold at home and in the foreign country.

It follows that

$$\frac{P_{\mathrm{H}}}{P_{\mathrm{F}}} = \frac{P_{\mathrm{H}}^*}{P_{\mathrm{F}}^*} = \frac{P_{\mathrm{H}}}{SP_{\mathrm{F}}^*} \tag{17}$$

Under the PCP assumption, both P_{H} and P_{F}^* are fixed *ex ante* and do not respond to shocks to demand or money supply. Define $\kappa \equiv P_{\mathrm{H}}/P_{\mathrm{F}}^*$. Because these nominal prices are set in advance of the realization of the state, κ does not depend on the outcomes of the random variables. Then the relative price of home to foreign goods varies inversely with the exchange rate:

$$\frac{P_{\mathrm{H}}}{P_{\mathrm{F}}} = \frac{\kappa}{S}$$

Substituting in the expression for the equilibrium exchange rate, we get under PCP pricing

$$\frac{P_{\mathrm{H}}}{P_{\mathrm{F}}} = \kappa \frac{M^*}{M} \tag{18}$$

In fact, we can find monetary policy rules that allow the equilibrium to exactly mimic the flexible price equilibrium:

$$M = \frac{\chi}{\mu\eta} P_{\mathrm{H}} \qquad M^* = \frac{\chi}{\mu\eta^*} P_{\mathrm{F}}^* \tag{19}$$

Using these expressions, and $P_{\mathrm{H}} = SP_{\mathrm{H}}^*$ and $P_{\mathrm{F}} = SP_{\mathrm{F}}^*$, we get

$$\frac{P_{\mathrm{H}}}{P_{\mathrm{F}}} = \frac{P_{\mathrm{H}}^*}{P_{\mathrm{F}}^*} = \frac{\eta}{\eta^*}$$

which is exactly the expression for relative prices under flexible exchange rates, equation (12). This result depends on nominal exchange rate flexibility. Monetary rules target local supply shocks (i.e. home money targets home supply shocks, foreign money targets foreign supply shocks). The equilibrium exchange rate is given by equation (7).

Using equation (19), the money market equilibrium conditions (4), and the definition of the price index (2), we find that aggregate con-

sumption C is exactly the same as in the flexible price model given in equation (14). Since purchasing power parity holds, the risk-sharing condition gives us that $C = C^*$, as in the flexible price model.

Using the same equations, along with the demand equations (6), we find that employment in the PCP model under the specified monetary reaction functions is identical to the flexible price employment levels, given by equations (15) and (16).

Obstfeld and Rogoff (2000) demonstrate that mimicking the flexible price allocation is the constrained globally efficient monetary policy. While the flexible price equilibrium itself is not Pareto efficient (because of the monopoly distortions), optimal monetary policy can do no better than to replicate the flexible price allocation. Moreover the monetary policy I set out above is, as Obstfeld and Rogoff (2002) show, the policy that self-interested national economic planners would follow. That is, there is no gain to international monetary coordination. Central banks following policies that maximize their own country's welfare can achieve the constrained globally efficient outcome.

This model, however, has implications that are counterfactual: that exchange rate changes are passed through one-for-one into consumer prices, and that the law of one price holds for all goods. It is this characteristic of the model that has led some researchers to consider the local-currency pricing version of the sticky nominal price model.

5 Sticky Prices: LCP Case

An alternative model for price setting is that firms set prices in the currency of consumers of the product. That is, when a home firm sells in the home market it sets prices in the home currency. But for sales to the foreign market, it sets prices in the foreign currency. We call this the LCP (for 'local-currency pricing') case. Betts and Devereux (1996, 2000) and Chari *et al.* (2000) are examples of models that have made the LCP assumption.

It follows immediately in this case that a flexible nominal exchange rate cannot achieve the optimal relative price adjustment. P_{h} and P_{f} are both set in the domestic currency and do not respond to contemporaneous shocks. We cannot replicate the flexible price solution of $P_{\mathrm{H}}/P_{\mathrm{F}} = P^*_{\mathrm{H}}/P^*_{\mathrm{F}} = \eta/\eta^*$ with flexible exchange rates, no matter what the monetary policy.

Labor supply allocations therefore cannot match the equilibrium labor allocations under flexible prices. We have, for example, $C_{\mathrm{H}} = \alpha^{\lambda}(P/P_{\mathrm{H}})^{\lambda}C$ and $C^*_{\mathrm{H}} = \alpha^{\lambda}(P^*/P^*_{\mathrm{H}})^{\lambda}C^*$. Since P/P_{H} and P^*/P^*_{H} are both fixed *ex ante*—and thus are not responsive to supply shocks—it follows that supply shocks affect C_{H} and C^*_{H} only through their influence on C and C^*. Under flexible prices, equation (15) shows that home employment L is inversely

related to home leisure preference shocks η. With home employment given by $L = \frac{1}{2}C_{\mathrm{H}} + \frac{1}{2}C^*_{\mathrm{H}}$, we would somehow need to have a policy where C and C^* respond inversely to η in order to replicate the flexible price behavior for L. But such a policy would then make it impossible to replicate the flexible price outcomes for C and C^* given in equation (14), or the flexible price solution for foreign employment given in equation (16).

Since $C = C^*$, monetary policy could replicate the flexible price outcome for aggregate consumption, but only if monetary reaction functions respond identically in the home and foreign country to shocks. That is, if

$$M = P\chi\mu^{-1}\left[\alpha\eta^{1-\lambda} + (1-\alpha)\eta^{*1-\lambda}\right]^{-1/(1-\lambda)} \tag{20}$$

and

$$M^* = P^*\chi\mu^{-1}\left[\alpha\eta^{1-\lambda} + (1-\alpha)\eta^{*1-\lambda}\right]^{-1/(1-\lambda)} \tag{21}$$

then the consumption levels under flexible prices, given by equation (14), can be replicated under LCP. Devereux and Engel (2001) show that these policies are optimal under LCP. They imply that exchange rates will be fixed at the purchasing power parity level:

$$S = \frac{M}{M^*} = \frac{P}{P^*} \tag{22}$$

There is a simple way to understand the striking difference in optimal policy in the PCP world versus the LCP world. There are two types of deviations from efficiency which monetary policy might be able to rectify in a sticky price world. One is that relative prices might not respond in the correct way to real shocks, so that we might not achieve $P_{\mathrm{H}}/P_{\mathrm{F}} = P^*_{\mathrm{H}}/P^*_{\mathrm{F}} = \eta/\eta^*$. In the absence of optimal relative price changes, consumers do not receive the correct signals and do not alter their demand for goods in the appropriate way when real shocks hit. As a consequence, resources will not be allocated efficiently.

The other type of inefficiency comes because deviations from purchasing power parity lead to incomplete risk sharing. As noted above, with a complete set of nominal contingent claims traded, in equilibrium $C^{-\rho}/P = C^{*-\rho}/SP^*$. Asset markets do not deliver complete risk sharing unless purchasing power parity holds, $P = SP^*$.

When prices are set in producers' currencies (PCP), purchasing power parity holds, so asset markets deliver complete risk sharing. In that case, monetary policy can be devoted entirely toward ensuring that relative prices respond in the appropriate way to real shocks.

Under local-currency pricing, relative prices cannot change in the short run in response to real shocks. It is useless for monetary policymakers to devote any effort to achieving an efficient relative price

response. But, under LCP, both P and P^* are predetermined and not affected by real shocks. If the nominal exchange rate is fixed so that purchasing power parity holds, asset markets will achieve complete risk sharing.

This model is also apparently consistent with the empirical evidence that consumer prices are unresponsive to exchange rate changes in the model. The law of one price does not hold in the model: $P_{\mathrm{h}} \neq SP_{\mathrm{h}}^*$ and $P_{\mathrm{f}} \neq SP_{\mathrm{f}}^*$.

In essence, Devereux and Engel (2001) take the evidence against the law of one price for consumer goods as support for the position that nominal exchange rate changes are not capable of achieving desirable relative price changes.

6 Imports as Intermediates

Consider this alternative interpretation of the general model. Consumers in each country get utility from a single consumption product. In the home country that consumption is C, and in the foreign country it is C^*. Utility is still given by U and U^*, as defined in Section 2, with suitable re-interpretation.

In each country, final output is distributed by a competitive distribution sector. The distribution sector produces the final good using inputs from home and foreign monopolists. The production function for final output in the home country is given by

$$X = \left[\alpha^{1/\lambda} X_{\mathrm{H}}^{(\lambda-1)/\lambda} + (1-\alpha)^{1/\lambda} X_{\mathrm{F}}^{(\lambda-1)/\lambda}\right]^{\lambda/(\lambda-1)} \tag{23}$$

The production function for output in the foreign country is identical. Note that this is simply the utility function from Section 2, but now in the guise of a production function in which final output X is produced from goods manufactured in the home country, X_{H}, and goods manufactured in the foreign country, X_{F}, using CES technology. These terms, in turn, are CES aggregates. X_{H} is an aggregate of a continuum of goods produced in the home country, and X_{F} is an analogous function for goods produced in the foreign country.

The cost of final output is determined from the cost function:

$$\Gamma = \left[\alpha P_{\mathrm{H}}^{1-\lambda} + (1-\alpha) P_{\mathrm{F}}^{1-\lambda}\right]^{1/(1-\lambda)} \tag{24}$$

This, of course, is identical to the price index defined in equation (2) in Section 2. We assume the distribution sector is competitive, and there is free entry. In cases in which distributors do not set prices in advance (i.e. in our reinterpretation of the flexible price model, the PCP model and the LCP model), $P = \Gamma$.

Equations (6) can be reinterpreted as derived demand curves. Total market demand for home-produced and foreign-produced goods is then

$$X_{\mathrm{H}} = \alpha^{\lambda}\left(\frac{\Gamma}{P_{\mathrm{H}}}\right)^{\lambda} C \qquad X_{\mathrm{F}} = (1-\alpha)^{\lambda}\left(\frac{\Gamma}{P_{\mathrm{F}}}\right)^{\lambda} C \tag{25}$$

The rest of the model of Section 2 goes through unchanged.

The PCP and LCP models can be interpreted as having a distribution sector that sells the consumer good at the cost of producing it. The PCP model, then, is one in which there is full pass-through of exchange rates to imported goods. Producers of intermediate goods set prices in their own currency. The distributors then sell the final good at cost to consumers. Exchange rate changes are passed along to consumers to the extent that foreign goods are used in the output of final goods.

The LCP model is now one in which there is no pass-through of exchange rates to import prices. Home producers, for example, set one price for sale to distributors in their own country (denominated in the home country's currency) and another price set in foreign currency for sale to distributors in the foreign country. Again, distributors sell the good at cost to consumers. So, consumer prices in each country are fixed in the consumers' currency.

Consider a third possibility: full pass-through to import prices, but local-currency pricing for consumers. Such a configuration is more consistent with the empirical evidence of very low pass-through of exchange rates to consumer prices, but greater pass-through to import prices. The model I describe here is related closely to, and is really a mix between, the models of Devereux *et al.* (1999) and Obstfeld (2001). McCallum and Nelson (2000) make similar assumptions.

This model, then, is completely consistent with the observation that consumer prices do not respond much to exchange rate changes in the short run. But there is still an important role for exchange rate flexibility in changing relative prices. The final goods producers face a 'sourcing' decision—to use imported intermediates or locally produced intermediates. There is not perfect substitutability between the two, but there is some—an elasticity of λ, to be precise.[4] So, a nominal exchange rate adjustment can change the price of imported relative to locally produced intermediates.

There is a single final consumer good, sold by the competitive distribution sector that buys intermediate inputs in competitive markets. We assume distributors are risk neutral. The price of the final good in the home country is P, and it is fixed in home currency. Distributors can enter

[4]In Obstfeld's framework there is a unitary elasticity of substitution. In Devereux *et al.* (1999), it is zero.

the market before the realization of shocks. Since the sector is competitive, and distributors are risk neutral, entry occurs until expected profits are driven to zero. The price set *ex ante* for consumers is equal to the expected cost of goods.

The cost of producing the consumption good is not fixed *ex ante*. We assume that P_{H} and P_{F}^{*} are fixed *ex ante*. For the home distributors, there is full pass-through of the exchange rate into the price they must pay for foreign intermediate goods, $P_{\mathrm{F}} = SP_{\mathrm{F}}^{*}$. So, using equation (24), the cost of a unit of final output is given by

$$\Gamma = \left[\alpha P_{\mathrm{H}}^{1-\lambda} + (1-\alpha)S^{1-\lambda}P_{\mathrm{F}}^{*1-\lambda}\right]^{1/(1-\lambda)} \tag{26}$$

Potentially there are wealth effects from exchange rate changes in this case. When the home currency depreciates, it raises the price that local distributors must pay for imported intermediate goods and lowers their profits. Prices are fixed for consumers (and hence their demand is fixed). With risk-neutral distributors and free entry *ex ante*, we have $P = E(\Gamma)$. So, home distributors suffer a loss in profits when the exchange rate increases. Foreign distributors have a windfall gain. But, as in Devereux *et al.* (1999), these profit effects are not consequential because of the assumption of complete markets.

With fixed nominal prices, we have for example in the home country $P_{\mathrm{H}}/P_{\mathrm{F}} = P_{\mathrm{H}}/SP_{\mathrm{F}}^{*}$. Since P_{H} and P_{F}^{*} will be fixed under the market conditions described, we need exchange rate flexibility to allow relative price adjustment. Indeed, since $S = M/M^{*}$ with a suitably designed monetary policy of the form $M = k/\eta$ and $M^{*} = k^{*}/\eta^{*}$, the flexible price outcome for relative prices, equation (12), can be reproduced.

But such a policy will necessarily lead to deviations from purchasing power parity. The policy described above implies that the nominal and real consumption exchange rate fluctuates with supply shocks, because P and P^{*} are fixed *ex ante*:

$$\frac{SP^{*}}{P} = \frac{k}{k^{*}}\frac{P^{*}}{P}\frac{\eta^{*}}{\eta}$$

When purchasing power parity does not hold, then risk sharing is not perfect. There is a deviation from the flexible price outcome of $C = C^{*}$.

There is a genuine trade-off facing monetary policy-makers concerning the flexibility of nominal exchange rates. If nominal exchange rates moved enough, the relative prices facing distributors would be the same as under flexible goods prices (and PCP). Distributors would be getting the correct price signals. But that type of exchange rate flexibility leads to deviations from purchasing power parity, which lead to undesirable consequences for risk sharing.

Conversely, if monetary policy were set so that the exchange rate

was kept fixed at its purchasing power parity level, the risk-sharing goals could be met. Indeed, as in the LCP model, monetary policy could be used to replicate aggregate consumption levels of the flexible price model, and such a policy is consistent with maintaining fixed exchange rates. But, the drawback of such a policy is that distributors would be getting the wrong price signals. Relative prices of home and foreign goods would not change in response to labor supply shocks. There would be no response in home employment relative to foreign employment.

An optimal monetary policy must take both of these effects into consideration. There is a trade-off between achieving the efficient employment outcome and eliminating deviations from the law of one price for consumers. In a different set-up, Corsetti and Pesenti (2001) make much the same point.

7 Conclusions

Recent theoretical papers demonstrate that optimal monetary policy can replicate a flexible price environment if nominal price stickiness is of the sort that prices are set in producers' currencies. Nominal exchange rate movements can allow relative price adjustments to occur. Empirical evidence appears to contradict this assumption, because consumer prices are not very responsive to exchange rates. If there is no effect of exchange rates on prices that are paid by demanders of goods, then the exchange rate does not play the role of adjusting relative prices. However, we have seen an interpretation that still assigns an important relative price role to the exchange rate, yet can reconcile the evidence of low exchange rate pass-through to consumer prices.

It is sometimes argued that in the presence of local-currency pricing, there is a prima facie case for stable nominal exchange rates. Volatile nominal exchange rates can lead to large short-run deviations from the law of one price when goods prices are set in consumers' currencies. So, the case is made that fixing the exchange rate at the appropriate level can eliminate the distortion that arises when consumers face different prices for identical goods. But Engel and Rogers (2001) demonstrate that the logic of this argument is not airtight. Fixing the exchange rate, or joining a currency union, entails altering monetary policy, which in itself has welfare implications. That paper produces a simple example to show that the loss of independence of monetary policy might entail a cost equal in size to the welfare costs of deviations from the law of one price. Devereux and Engel (2001) find fixed exchange rates are optimal under LCP when monetary policy rules are optimal. The example in Engel and Rogers (2001) is one where exchange rates are fixed but monetary policy rules are suboptimal.

The example of Engel and Rogers (2001), as well as all of the models

discussed here, assume that the exchange rate is driven by monetary and real factors, and there is no significant role for speculative bubbles. If bubbles are important in determining exchange rates, then perhaps a stronger case for fixed exchange rates or currency union can be made. Bubbles would cause real distortions, especially under local-currency pricing.

The new open economy macroeconomics has given us a structured way to think about the issues that are important when considering the desirability of floating exchange rates versus currency union. Unfortunately for policy-makers facing a near-term deadline for choosing an exchange rate system, our knowledge has not advanced far enough to offer a firm recommendation backed up by appropriate theory. We will undoubtedly see many advances in this area of research over the next decade, further refining the models to determine exactly what matters for the choice of exchange rate regime. In addition, the models point the direction for empirical researchers to take to gather the precise information we need to calibrate the size of the expenditure-switching role for exchange rates.

References

Betts, C. and Devereux, M. B. (1996). 'The Exchange Rate in a Model of Pricing-to-market', *European Economic Review*, Vol. 40, pp. 1007–1021.

Betts, C, and Devereux, M. B. (2000). 'Exchange Rate Dynamics in a Model of Pricing-to-market', *Journal of International Economics*, Vol. 50, pp. 215–244.

Chari, V. V., Kehoe, P. J. and McGrattan, E. R. (2000). 'Can Sticky Price Models Generate Volatile and Persistent Exchange Rates?', *National Bureau of Economics Research Working Paper 7869*.

Corsetti, G. and Pesenti, P. (2001). 'International Dimensions of Optimal Monetary Policy', University of Rome III, manuscript.

Devereux, M. B. and Engel, C. (2001). 'Monetary Policy in the Open Economy Revisited: Exchange Rate Flexibility and Price Setting Behavior', University of Wisconsin—Madison, manuscript.

Devereux, M. B., Engel, C. and Tille, C. (1999). 'Exchange Rate Pass-through and the Welfare Effects of the Euro', *National Bureau of Economic Research Working Paper 7382*.

Engel, C. (1993). 'Real Exchange Rates and Relative Prices: an Empirical Investigation', *Journal of Monetary Economics*, Vol. 32, pp. 35–50.

Engel, C. (1999). 'Accounting for U.S. Real Exchange Rate Changes', *Journal of Political Economy*, Vol. 107, pp. 507–538.

Engel, C. (2000). 'Local-currency Pricing and the Choice of Exchange-rate Regime', *European Economic Review*, Vol. 44, pp. 1149–1472.

Engel, C. and Rogers, J. H. (1996). 'How Wide is the Border?', *American Economic Review*, Vol. 86, pp. 1112–1125.

Engel, C. and Rogers, J. H. (2001). 'Deviations from the Purchasing Power Parity: Causes and Welfare Costs', *Journal of International Economics*, Vol. 55, pp. 29–57.

Goldberg, P. K. and Knetter, M. M. (1997). 'Goods Prices and Exchange Rates: What Have We Learned?', *Journal of Economic Literature*, Vol. 35, pp. 1243–1272.

McCallum, B. T. and Nelson, E. (2000). 'Monetary Policy for an Open Economy: an Alternative Framework with Optimizing Agents and Sticky Prices', *Oxford Review of Economic Policy*, Vol. 16, pp. 74–91.

Mussa, M. (1986). 'Nominal Exchange Rate Regimes and the Behavior of Real Exchange Rates: Evidence and Implications', *Carnegie-Rochester Conference Series on Public Policy*, Vol. 25, pp. 117–213.

Obstfeld, M. (2001). 'International Macroeconomics: Beyond the Mundell–Fleming Model', *IMF Staff Papers*, Vol. 47 (Special Issue), pp. 1–39.

Obstfeld, M. and Rogoff, K. (1995). 'Exchange Rate Dynamics Redux', *Journal of Political Economy*, Vol. 103, pp. 624–660.

Obstfeld, M. and Rogoff, K. (2000). 'New Directions for Stochastic Open Economy Models', *Journal of International Economics*, Vol. 50, pp. 117–153.

Obstfeld, M. and Rogoff, K. (2002). 'Global Implications of Self-oriented National Monetary Rules', *Quarterly Journal of Economics*, Vol. 117, pp. 503–535.

Obstfeld, M. and Taylor, A. M. (1997). 'Non-linear Aspects of Goods Market Arbitrage and Adjustment: Heckscher's Commodity Points Revisited', *Journal of the Japanese and International Economies*, Vol. 11, pp. 441–479.

Parsley, D. C. and Wei, S.-J. (2001a). 'Explaining the Border Effect: the Role of Exchange Rate Variability, Shipping Costs and Geography', *Journal of International Economics*, Vol. 55, pp. 87–105.

Parsley, D. C. and Wei, S.-J. (2001b). 'Limiting Currency Volatility to Stimulate Goods Market Integration: a Price Based Approach', Owens Graduate School of Management, Vanderbilt University, manuscript.

Rogers, J. H. and Jenkins, M. (1995). 'Haircuts or Hysteresis? Sources of Movements in Real Exchange Rates', *Journal of International Economics*, Vol. 38, pp. 339–360.