Exchange Rate Policy and Endogenous Price Flexibility*

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Abstract

A fixed exchange rate limits the ability of the real exchange rate to adjust to shocks, and tends to raise the volatility of real GDP. But adjustment may be enhanced if internal prices are more flexible under a fixed exchange rate. This paper develops a model in which price setters incur a cost to retain the option of ex-post price flexibility. The benefit of flexibility is increasing in the variance of demand facing price setters. We ask whether fixing the exchange rate is likely to increase price flexibility. For a unilateral peg followed by one country alone, the answer is yes. Moreover, because there is a strategic complementarity in the choice of price flexibility, the increase in flexibility following an exchange rate peg can be very large. It is even possible that the increase in internal flexibility following an exchange rate peg is so great that it overturns the direct effect, and GDP is more *stable* after a peg. On the other hand, when an exchange rate peg is supported by bilateral participation of both monetary authorities (such as a monetary union), the degree of price flexibility may actually be *less* than under freely floating exchange rates. The model also allows for multiple, self-fulfilling equilibria in the degree of price flexibility.

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The most popular argument for flexible exchange rates is that they enhance the ability of the economy to respond to shocks, in the presence of nominal rigidities (e.g. Friedman 1953). But an oft-cited qualification to this is that by eliminating the use of the exchange rate as a mechanism for adjustment, an exchange rate peg may increase internal price flexibility within a country. This has been especially important in the analysis of the conditions for single (small) countries to follow unilateral `hard peg' policies, fixing the exchange rate under a currency board or dollarization rule. Since these countries will generally not have access to compensating policy responses from the monetary authorities of the currency to which they are pegging, the need to increase internal price flexibility after a peg becomes more critical. Another area where this discussion is important is that of the impact of a monetary union on flexibility. To the extent that a single currency encourages price flexibility within the different regions of the monetary union, this will reduce the loss from the absence of exchange rate adjustment. To this extent, the economic case for a monetary union may be enhanced by the formation of the monetary union, as suggested by Frankel and Rose (1998).

Is price flexibility likely to take place automatically in response to changes in monetary policy conditions, through the decisions of individual price setters? We could think of price stickiness as being determined by the trade-off between `costs of price flexibility' (information or planning costs, for instance) and benefits of ex post price adjustment. These benefits would be higher, the more volatile is the environment within which a price setter operates. If an exchange rate peg substantially increases the volatility of demand for their product, the elimination of the exchange rate as a policy lever may cause price setters to adjust more frequently.

This paper provides a theoretical investigation of the implications of exchange rate rules for the flexibility of nominal prices, in an economy where price flexibility is itself endogenous. In a two-country model, there are shocks to relative national demands, and country specific velocity shocks. Given the uncertainty faced by price-setters, due to these shocks, they may choose ex-ante to incur a cost so as to have the flexibility to adjust their prices ex-post. Within this setting, we ask a) what features determine the equilibrium degree of price flexibility, and b) in what way does an exchange rate peg affect the degree of price flexibility?

The incentive for ex-post price flexibility for any one price-setter is increasing in the variability of *nominal demand* it faces for its good. But there is also a key *strategic complementarity* in the choice of flexibility[1]. This is because the incentive for flexibility is increasing in the total number of price setters who do adjust ex-post. If only a small number of price setters adjust their price, then there may be little incentive for the marginal price setter to pay the menu cost. But if all price setters choose to adjust, the volatility of prices will increase the overall volatility of demand facing a price setter, and hence all price setters may find it in their interest to adjust. , By strongly linking the decisions of each agent with that of other agents, the presence of strategic complementarity allows for changes in the external environment to have a potentially very large effect on the equilibrium degree of price flexibility.

How does exchange rate policy affect the degree of price flexibility? We find that a one sided peg, followed by a single country in face of a passive monetary authority of the currency to which the country is pegging, will lead to enhanced price flexibility for the pegging country, if both countries have similar sized shocks. A one

[1] Strategic complementarities in macroeconomics were first emphasized by Cooper and John (1988). In the context of this paper, the most relevant predecessor is Ball and Romer (1991), who emphasize the importance of strategic complementarities in a model of price setting by monopolistic competitive agents.

sided peg requires the country to offset relative demand shocks hitting the country, and also allows the monetary authority to offset domestic velocity shocks. Without the active participation of the foreign monetary authority however, the country must also `import' volatility from foreign velocity shocks. The upshot is that the overall volatility of nominal demand facing price setters is raised, and price flexibility is enhanced. However, a bilateral (or cooperative) peg, involving active participation of all monetary authorities, may not have this same affect. In particular, if velocity shocks are the major source of exchange rate volatility, then a bilateral pegged exchange rate may in fact *reduce* equilibrium price flexibility. This is because a bilateral peg tends to eliminate the variability of nominal demand coming from both home and foreign velocity shocks.

How big is the impact of an exchange rate change on price flexibility? A natural presumption would be that, while the move to a unilateral peg may increase the degree of price flexibility, it would not offset the direct effect of the exchange rate peg on output volatility. Hence, the conventional view that a fixed exchange rate limits relative price adjustment, and magnifies the volatility of real GDP, would still apply. But in the presence of significant strategic complementarity, this reasoning can be incorrect. A unilateral peg will always increase the volatility of nominal demand facing price-setters, and increase their incentive to invest in flexibility. If there is substantial strategic complementarity in the choice of price flexibility, then there may be a very large increase in the share of price setters choosing the option of ex post flexibility. For a standard parameterization of the model, we find that this indirect effect of the exchange rate peg on price flexibility can offset the direct effect on the volatility of nominal demand. As a result, the volatility of GDP can be *less* after a unilateral peg than under flexible exchange rates.

The presence of strategic complementarity also opens up the possibility of multiple equilibrium in the degree of price flexibility. By increasing nominal volatility, a unilateral peg increases the likelihood of multiple equilibrium. Hence, a peg may give rise to the conditions for a dramatic rise in price flexibility to occur.

The paper is related to a large recent literature evaluating the effects of monetary rules in sticky price equilibrium models[2]. But our departure is in allowing for the degree of price stickiness itself to be an endogenous variable. In this respect, the paper is related to the literature on state-dependent pricing and menu-costs of price change (see Ball and Romer 1991, Dotsey, King and Wolman, 1999). The model is most closely related to Ball and Romer (1991). They show the possibility of multiple equilibrium, in an environment where price setters can choose *ex-post* whether to adjust prices, given a common menu cost of price change, within a one-country environment. Our analysis differs because we allow a distribution of firm specific menu costs, and we assume that price setters choose *in advance* whether or not to have the ex-post flexibility to adjust price. This is more in line with the view that a large change in monetary policy regime (e.g. fixing the exchange rate) may lead to structural changes in the flexibility of contracts within a monetary economy. Moreover, our focus is not primarily on multiple equilibrium, but more on the role of strategic complementarity in the choice of flexibility. Finally of course, we use a two country model.

The next section sets out the model. Section 2 examines the determination of equilibrium price flexibility in the model. Section 3 explores the impact of exchange rate policy on this equilibrium. Some conclusions follow.

Section 1: The Model

The determinants of the degree of price flexibility are illustrated within a two-country model, which comprises a `home' and a `foreign' country. All foreign variables are denoted with an asterisk. Individuals in each country are `yeoman farmers', producing a differentiated good and selling the good to home and foreign consumers at a price that they choose optimally. Within either country, every individual household faces a two-part choice with respect to its pricing policy. It first chooses whether to set its price in advance, or to wait and set its price ex-post, after the state of the world is known. The latter decision involves the household incurring a fixed cost. We think of this as a `cost of flexibility'. This cost will generally differ across households. Given this decision, then the household will choose what price to set, whether the price is set in advance, or adjusted to ex-post to the state of the world. There is a one period time horizon.

Households

In each country, there is a unit measure of total households. The home country consumer *i* maximizes the following utility function

(1.1) $$EU = E\left\{ \ln(C(i)) + \chi \ln(\frac{M(i)}{P}) - \eta \frac{H(i)^{1+\psi}}{1+\psi} - I(i) \right\}.$$

$C(i)$ is aggregate consumption, given by $C = \left(\frac{C_h(i)}{\gamma}\right)^{\gamma} \left(\frac{C_f(i)}{(1-\gamma)}\right)^{(1-\gamma)}$, where $C_j(i)$ is consumption of the *j'th* countries good, *j=h,f*. P is the price index, given by $P = P_h^{\gamma}(SP_f^*)^{(1-\gamma)}$, where S is the exchange rate and P_h (P_f^*) is the home (foreign) currency price of the home (foreign) good. The `law of one price' holds for each

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[2] See, among many other papers, Bacchetta and Van Wincoop (2000), Corsetti and Pesenti (2001), Benigno and Benigno (2003), Chari Kehoe, and McGratten (2002), Devereux and Engel (2003), Kollman (2002), Lane (2001), and Obstfeld and Rogoff (1995, 1998, 2000, 2002).

good. $M(i)$ is the quantity of domestic money held. The term $I(i)$ represents an indicator function related to the household-specific `cost of flexibility', measured in utility terms. If the household chooses to set its price in advance, then there is no cost of flexibility, and $I(i)=0$. But if it chooses the flexibility to adjust its price ex post, after the state of the world has been realized, then $I(i)=\Psi(i)$, where $\Psi(i)$ is the household-specific cost of flexibility. This cost is known by individual *i* in advance. We order the cost function across individuals so that, $\Psi(0)=0$, $\Psi(1)=\overline{\Psi}>0$, and $\Psi'(i)>0$.

There are two random variables associated with the preferences (1.1). The variable γ represents the relative preference for the home good. This is common across households and countries, and stochastic. This captures random preference shocks, shifting world demand for the good of the home country relative to the foreign country. We call this a *relative demand* shock. We let the distribution of γ be symmetric, bounded between 0 and 1, with mean 0.5. Relative demand shocks give rise to endogenous terms of trade movements.

The second shock is to χ, the coefficient on the utility of real money balances. This represents a shock to the velocity of money (this interpretation will become clearer below). We assume that χ has mean unity. In addition, we assume that χ is i.i.d. across countries.

Consumption of each country's good is differentiated across a continuum of goods with elasticity of substitution across goods equal to λ. Thus,

$$C_j(i)=\left(\int_0^1 C_j(i,v)^{1-\frac{1}{\lambda}}dv\right)^{\frac{1}{(1-\frac{1}{\lambda})}},\quad j=h,f\ .$$

The price indices for home and foreign goods are then defined as

$$P_h = \left[\int_0^1 P_h(v)^{1-\lambda} dv \right]^{\frac{1}{1-\lambda}}, \quad P_f^* = \left[\int_0^1 P_f^*(v)^{1-\lambda} dv \right]^{\frac{1}{1-\lambda}}$$

Budget Constraint

The budget constraint for household i is

(1.2) $$PC(i) + M(i) = P_h(i)H(i) + M_0 + T(i)$$

where $H(i)$ is the total output of household i's good, and $M_0 + T(i)$ represents initial money holdings, plus any tax or transfer from the monetary or fiscal authority. In principle, we allow transfers to be household-specific. In fact, we assume that transfers differ across fixed-price and flexible price households. This is a simplifying device, which is discussed more fully below.

Given income from sales of its good, after the state of the world is revealed, the household optimally divides income between consumption and money holdings. Optimal money holdings are

(1.3) $$\frac{M(i)}{P} = \chi C(i).$$

Demand for each of the two goods is

(1.4) $$C_h(i,v) = \gamma \left(\frac{P_h(v)}{P_h} \right)^{-\lambda} \frac{PC(i)}{P_h}, \quad C_f(i,v) = (1-\gamma) \left(\frac{P_f^*(v)}{P_f^*} \right)^{-\lambda} \frac{PC(i)}{SP_f^*}.$$

Price setting

The household producers in this economy choose whether to set their prices in advance, or to pay the fixed cost of flexibility, and set prices ex-post. In either case, they choose prices to maximize expected utility (or actual utility, for flexible-price households), subject to their demand functions, and consumer prices.

We may define household's utility as a function of their pre-set price $\hat{P}_h(i)$, when the price is not adjusted ex-post, as the implicit function

(1.5)

$$V(\hat{P}_h(i), P_h, P, X)$$
$$= \ln\left(\hat{P}_h(i)\left(\frac{\hat{P}_h(i)}{P_h}\right)^{-\lambda}\frac{X}{P} + \frac{M_0 + T(i) - M(i)}{P}\right) + \chi \ln\left(\frac{M(i)}{P}\right) - \frac{\eta}{1+\psi}\left(\left(\frac{\hat{P}_h(i)}{P_h}\right)^{-\lambda} X\right)^{(1+\psi)}$$

where X represents total demand for home goods[3]. If the household adjusts its price ex-post, we define the function

(1.6)

$$\tilde{V}(P_h, P, X)$$
$$= \max_{\tilde{P}_h(i)}\left\{\ln\left(\tilde{P}_h(i)\left(\frac{\tilde{P}_h(i)}{P_h}\right)^{-\lambda}\frac{X}{P} + \frac{M_0 + T(i) - M(i)}{P}\right) + \chi \ln\left(\frac{M(i)}{P}\right) - \frac{\eta}{1+\psi}\left(\left(\frac{\tilde{P}_h(i)}{P_h}\right)^{-\lambda} X\right)^{(1+\psi)}\right\}$$

All households that set price in advance will have the same consumption, and all households that adjust prices ex-post will receive the same consumption. But in general, consumption will differ across the two groups. Because households in the two groups will then require different cash balances to satisfy (1.3), there may arise a need for ex-post transfers of money between groups. To avoid this complication, we assume that government cash transfers are different for fixed-price and flexible-price households. In particular, we set $T(i)$ so that

(1.7) $\quad T(i) = M_0 + M(i)$.

This implies that the second term inside the first set of parentheses in (1.5) and (1.6) is zero, in equilibrium; i.e. households do not need to engage in ex-post within-country trade to obtain their desired money balances. This assumption is made for analytical simplicity only. It could easily be relaxed without changing the nature of the results, but it would complicate the form of the propositions derived below.

[3] We omit the M term from this function, since it will fall out in any case, due to the envelope condition.

For the household that sets price in advance, the ex ante price setting problem is described by

$$\max_{\hat{P}_h(i)} EV(\hat{P}_h(i), P_h, P, X) \quad .$$

Then substituting from the condition (1.5), using (1.7), the optimal ex ante price set by the firm will be determined by the condition

$$1 - \frac{\eta\lambda}{\lambda - 1} E(\hat{P}_h(i)^{-\lambda} P_h^{\lambda} X)^{1+\psi} = 0 \ .$$

This gives the optimal price equal to

$$\hat{P}_h(i) = (\eta\hat{\lambda})^{\frac{1}{\lambda(1+\psi)}} \left(E(P_h^{\lambda} X)^{1+\psi} \right)^{\frac{1}{\lambda(1+\psi)}} \tag{1.8}$$

where $\hat{\lambda} \equiv \dfrac{\lambda}{\lambda - 1}$.

If the firm chooses to adjust its price ex post, then it will set the price given by

$$\tilde{P}_h(i) = (\eta\hat{\lambda})^{\frac{1}{\lambda(1+\psi)}} P_h X^{\frac{1}{\lambda}} . \tag{1.9}$$

The total measure of households who adjust their price ex-post, z, is determined by the condition that if $0 < z < 1$, the *z'th* individual is ex-ante indifferent between adjusting and not adjusting. Otherwise, either all or no individuals will adjust. That is

(1.10) $EV(\hat{P}_h(i), P_h, P, X) = E\tilde{V}(P_h, P, X) - \Psi(z), \quad 0 < z < 1$

(1.11) $EV(\hat{P}_h(i), P_h, P, X) > E\tilde{V}(P_h, P, X) - \Psi(0), \quad z = 0$

(1.12) $EV(\hat{P}_h(i), P_h, P, X) < E\tilde{V}(P_h, P, X) - \Psi(1), \quad z = 1.$

It is clear from the conditions on the Ψ distribution that the second condition will never apply, because we have assumed that the menu costs incurred for the 0^{th} individual are zero, and in any stochastic environment there are strictly positive gains from being able to adjust the price ex post. Hence, the equilibrium z will be characterized by either $0 < z < 1$, or z=1.

We wish to examine the determinants of z, and in particular the impact of monetary policy and the exchange rate regime on the equilibrium z. In order to do this, we must characterize the equilibrium to the model, conditional on the ex-ante choice of prices, and the measure z and z^* of flexible price agents in each economy. An equilibrium is described by the conditions that each individual in category z (z^*) sets an optimal price, each household chooses an optimal pattern of consumption across goods and money holdings, given their budget constraint, and all markets clear. The full equilibrium is described in the list of equations set out in Table 1 below.

Table 1		
1. Money demand (fixed price)	$\frac{\hat{M}}{P} = \chi \hat{C}$	$\frac{\hat{M}^*}{P^*} = \chi \hat{C}^*$
2. Money demand (flexible price)	$\frac{\tilde{M}}{P} = \chi \tilde{C}$	$\frac{\tilde{M}^*}{P^*} = \chi^* \tilde{C}^*$
3. Money market clearing	$M_0 + (1-z)\hat{T} + z\tilde{T}$ $= (1-z)\hat{M} + z\tilde{M}$	$M_0^* + (1-z^*)\hat{T}^* + z^*\tilde{T}^*$ $= (1-z^*)\hat{M}^* + z^*\tilde{M}^*$
4. Fixed price	$\hat{P}_h = (\eta\hat{\lambda})^{\frac{1}{\lambda(1+\psi)}} \left(E(P_h^{\lambda} X)^{1+\psi} \right)^{\frac{1}{\lambda(1+\psi)}}$	$\hat{P}_f^* = (\eta\hat{\lambda})^{\frac{1}{\lambda(1+\psi)}} \left(E(P_f^{*\lambda} X^*)^{1+\psi} \right)^{\frac{1}{\lambda(1+\psi)}}$
5. Flexible price	$\tilde{P}_h = (\eta\hat{\lambda})^{\frac{1}{\lambda(1+\psi)}} P_h X^{\frac{1}{\lambda}}$	$\tilde{P}_f^* = (\eta\hat{\lambda})^{\frac{1}{\lambda(1+\psi)}} P_f^* X^{*\frac{1}{\lambda}}$
6. Price index	$P_h = \left((1-z)\hat{P}_h^{1-\lambda} + z\tilde{P}_h^{1-\lambda} \right)^{\frac{1}{1-\lambda}}$	$P_f^* = \left((1-z^*)\hat{P}_f^{*(1-\lambda)} + z^*\tilde{P}_f^{*(1-\lambda)} \right)^{\frac{1}{1-\lambda}}$
7. Budget constraint (fixed price)	$P\hat{C} + \hat{M} = \hat{P}_h\hat{H} + M_0 + \hat{T}$	$P^*\hat{C}^* + \hat{M}^* = \hat{P}_f^*\hat{H}^* + M_0^* + \hat{T}^*$
8. Budget constraint (flexible price)	$P\tilde{C} + \tilde{M} = \tilde{P}_h\tilde{H} + M_0 + \tilde{T}$	$P^*\tilde{C}^* + \tilde{M}^* = \tilde{P}_f^*\tilde{H}^* + M_0^* + \tilde{T}^*$

Table 1, continued		
9. Output (fixed price)	$\hat{H} = \left(\frac{\hat{P}_h}{P_h}\right)^{-\lambda} X$	$\hat{H}^* = \left(\frac{\hat{P}_f^*}{P_f^*}\right)^{-\lambda} X^*$
10. Output (flexible price)	$\tilde{H} = \left(\frac{\tilde{P}_h}{P_h}\right)^{-\lambda} X$	$\tilde{H}^* = \left(\frac{\tilde{P}_f^*}{P_f^*}\right)^{-\lambda} X^*$
11. Output (aggregate)	$H = ((1-z)\hat{H}^{1-\frac{1}{\lambda}} + z\tilde{H}^{1-\frac{1}{\lambda}})^{\frac{1}{1-\frac{1}{\lambda}}}$	$H^* = ((1-z^*)\hat{H}^{*(1-\frac{1}{\lambda})} + z^*\tilde{H}^{*(1-\frac{1}{\lambda})})^{\frac{1}{1-\frac{1}{\lambda}}}$
12. Demand	$X = \gamma \frac{P((1-z)\hat{C} + z\tilde{C})}{P_h} + \gamma \frac{SP^*((1-z^*)\hat{C}^* + z^*\tilde{C}^*)}{P_h}$	$X^* = (1-\gamma)\frac{P((1-z)\hat{C} + z\tilde{C})}{SP_f^*} + (1-\gamma)\frac{SP^*((1-z^*)\hat{C}^* + z^*\tilde{C}^*)}{SP_f^*}$

In the first four cells of Table 1, money demand for home and foreign households of both the fixed and flexible price category is defined. The sum of money demand must equal total money supply in each country. The next 6 cells define the prices set by the fixed and flexible price households, in each country, and the aggregate price index for the country. Cells 7 and 8 define the budget constraints for the fixed and flexible price households, in each country. Given prices and total demand *X,* cells 9 and 10 determine output of each price category in each country, while cells 11-12 define aggregate output and aggregate demand in each country. Table 1 gives 24 equations in 23 variables $\hat{M}, \tilde{M}, \hat{M}^*, \tilde{M}^*, \hat{P}_h, \tilde{P}_h, P_h, \hat{P}_f^*, \tilde{P}_f^*, P_f^*, \hat{C}, \tilde{C}, \hat{C}^*, \tilde{C}^*, \hat{H}, \tilde{H}, \hat{H}^*, \tilde{H}^*$, H, H^*, X, X^*, S, with one redundancy by Walras' Law.

Although the model implies an ex-post heterogeneity across households, it is not necessary to use this in order to determine the equilibrium degree of price flexibility. This is because we can aggregate across output of fixed and flexible price households, and determine that aggregate demand is a function of the aggregate variable alone. To see this, note that, from cells 9 and 10, we have $\hat{P}_h(1-z)\hat{H} + \tilde{P}_h z\tilde{H} = P_h X$. Then, combining cells 1-3 (money market equilibrium conditions) and 7,8 (budget constraints), we have $\hat{P}_h(1-z)\hat{H} + \tilde{P}_h z\tilde{H} = \hat{P}\hat{C} + \tilde{P}\tilde{C} = \dfrac{M}{\chi}$. From cells 12 (goods market equilibrium), we have the partial solution for the exchange rate given by $S = \dfrac{1-\gamma}{\gamma}\dfrac{X}{X^*}\dfrac{P_h}{P_f^*}$. Then putting these together, we get

$$S = \frac{1-\gamma}{\gamma}\frac{M}{\chi}\frac{\chi^*}{M^*} \tag{1.13}$$

An expansion in the home money supply causes an exchange rate depreciation. But a shift in relative demand towards the home good (rise in γ) will cause an appreciation of the home currency. Likewise, a rise in home velocity χ, causes an appreciation.

From these derivations, we obtain the result that

$$X = \frac{M}{\chi P_h}, \qquad X^* = \frac{M^*}{\chi^* P_f^*}. \tag{1.14}$$

That is, aggregate demand for home and foreign goods depends positively on real money balances expressed in units of each country's good, and negatively on the shocks to the velocity of money.

Section 2. The Determination of Optimal Price Flexibility

Given the solutions for prices and aggregate demand, we may return to the investigation of equilibrium price flexibility. Conditions (1.10)-(1.12) determine the measure of flexible price firms *z* in home country. To gain insight into the determination of z, we may take a second order approximation of the right hand side of condition (1.9), beginning at an initial non-stochastic equilibrium where $\bar{P}_h(i) = \bar{P}_h = \left(\eta\hat{\lambda}\right)^{\frac{1}{1+\psi}} \frac{\bar{M}}{\bar{\chi}}$. This gives

$$(2.1) \qquad E\left\{V(\hat{P}_h(i), P_h, P, X) - \tilde{V}(P_h, P, X)\right\} \approx \frac{(\lambda-1)}{\lambda}\frac{(1+\psi)}{2}\text{var}((\lambda-1)p_h + m - \hat{\chi})$$

where lower-case letters represent log deviations from the non-stochastic equilibrium price level[4]. To determine the behaviour of P_h, we use condition (2.1) in combination with the home country price index, stated as $P_h = \left[z\tilde{P}_h^{1-\lambda} + (1-z)\hat{P}_h^{1-\lambda}\right]^{\frac{1}{1-\lambda}}$, which gives $p_h = \dfrac{\frac{z}{\lambda}(m-\hat{\chi})}{(1 - z\frac{(\lambda-1)}{\lambda})}$. Substituting into (2.1), we arrive at the joint condition

$$(2.2a) \qquad \frac{(\lambda-1)(1+\psi)}{2\lambda}\frac{1}{(1-z\frac{(\lambda-1)}{\lambda})^2}\text{var}(m-\hat{\chi}) = \Psi(z), \quad 0 < z < 1$$

$$(2.2b) \qquad \frac{(\lambda-1)\lambda(1+\psi)}{2}\text{var}(m-\hat{\chi}) \geq \Psi(1), \quad z = 1.$$

Note that (2.2a) and (2.2b) depends only on the properties of home country aggregate demand. Then, from our solutions so far, we can establish the following Proposition

Proposition 1

Equilibrium price flexibility in each country is governed only by *domestic* aggregate demand conditions and the distribution of γ (the relative demand shock).

Proof: see conditions (2.2).

Hence equilibrium *z* is independent of foreign monetary policy or χ^*. Although this result is special to the model, depending in particular on the unit elasticity of substitution between home and foreign goods, it is very convenient for characterizing the determinants of equilibrium price flexibility.

Figure 1 illustrates the condition that determines z. The VV locus represents the left hand side of condition (2.2a or b). This represents the benefit of flexibility to the marginal price-setter. From both (2.1) and (2.2) we see that this is increasing in the variance of *nominal demand* facing the price-setter. The CC locus represents the cost distribution, or the right hand side of (2.2a or b). This represents the cost of flexibility to the marginal price-setter. The CC locus is upward sloping by assumption; the marginal firms have higher and higher costs of flexibility. The VV locus is upward sloping because as z rises, the home country price index becomes more volatile, and this increases the gain to any one household from allowing its price to be ex-post flexible. It is clear from this characterization of the problem that there may be more than one equilibrium. Figure 1a describes a situation with a unique equilibrium, where the VV curve crosses the CC curve just once. Figure 1b describes a situation where the VV curve intersects twice with the CC curve. In this case there are three equilibria, one with a low value of *z*, one with $z=1$, and one intermediate equilibrium. The key difference between Figure 1a and Figure 1b is the magnitude of the elasticity of demand λ. With a low elasticity, the VV curve is rather flat, and the equilibrium is unique. But with a higher elasticity, the gains from ex-post flexibility are rising quickly in the measure of individuals who choose this, and there are two very different stable equilibria. In one equilibrium a small measure of individuals

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[4] The appendix derives expression (2.1).

choose to pay the costs of flexibility, in particular these are individuals with very low personal costs. In the other equilibrium, there is a self-fulfilling outcome where all firms choose to adjust prices ex-post, because all others do.

In general, for different assumptions regarding $\Psi(i)$, there may be multiple crossing points, and a high-flexibility stable equilibrium may not be associated with complete price flexibility. It is possible that there exist multiple stable equilibria, as described in Figure 1c, if the CC curve is shaped as in the Figure.

In the special case of a uniform distribution for $\Psi(i)$, we may state conditions for uniqueness of *z* in the following way.

Proposition 2

Assume that $\Psi(i) = \bar{\Psi} i$, where $\bar{\Psi}$ is a constant. Then the equilibrium *z* is unique if a) $\Theta(z) = g, \quad 0 < z < 1$ and $\Theta(1) > g$, or b) $\Theta(z) < g, \quad 0 \le z \le 1$, where

$$\Theta(z) = \bar{\Psi} z (1 - z\frac{(\lambda-1)}{\lambda})^2 \text{, and } g = \frac{(\lambda-1)(1+\psi)}{2\lambda} \text{var}(m - \hat{\chi}) \; .$$

Proof: This is straightforward to see from Figure 1a and 1b. Inspection of (2.2) reveals that the VV locus in strictly convex. If the $\Psi(i)$ distribution is uniform, the CC curve is a straight line. Then there is either one (case a), or zero (case b), intersections of the VV and CC loci. The conditions of the Proposition rule out more than one intersection.

Section 3. The Exchange Rate Regime and Equilibrium Price Flexibility

We now wish to investigate the impact of monetary policy and the exchange rate regime on the equilibrium degree of price flexibility. In this section, we assume that the conditions for a unique equilibrium with $0 < z < 1$ are satisfied. From condition (2.2), it is then immediate to see that an increase in the volatility of monetary policy or velocity will increase the degree of price flexibility. To see how exchange rate policy will affect price flexibility, note that we may write the solution for the exchange rate (from equation 1.13), in log deviation form, as

$$s = m - m^{*} + (\hat{\chi}^{*} - \hat{\chi}) - 2\hat{\gamma} \tag{3.1}$$

There are a number of ways in which an exchange rate policy may be defined within this model. This requires us to specify both the form of monetary rules, and the degree to which each country participates in the monetary policy. With respect to the form of the monetary rules, the outcome will depend on whether the monetary authority can respond directly to the ex-post realization of shocks, or targets an intermediate variable such as the exchange rate. Arguably, it is more realistic to assume that the authorities cannot directly target the ex-post values of the shocks. Hence, we assume that monetary authorities pursue a rule where they adjust the money supply in response to deviations of the exchange rate from the non-stochastic equilibrium level[5]. With respect to the participation of each monetary authority, we can define a unilateral or one-sided exchange rate policy as a situation where the home country alone follows a monetary rule to target the value of the exchange rate. Alternatively, a bilateral (or cooperative) exchange rate policy is one where both monetary authorities target the exchange rate[6]. We define the *intervention* coefficient on the exchange rate as the value of μ. In a one-sided policy, the home country monetary authority follows the rule $m = -\mu s$. Under a bilateral policy, the home and foreign monetary authorities follow the rules $m = -\frac{\mu}{2}s, \quad m^{*} = \frac{\mu}{2}s$, respectively. In either case, we may write the value of the exchange rate as

$$s = \frac{(\hat{\chi}^{*} - \hat{\chi}) - 2\hat{\gamma}}{1 + \mu} \tag{2.3}$$

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[5] It is simple to investigate the case where the monetary authorities can directly target shocks.
[6] This terminology was introduced by Helpman (1981).

When $\mu = 0$, there is a freely floating exchange rate, while a fixed exchange rate obtains when $\mu \to \infty$.

Using (2.3), we may now state

Proposition 3

Under a one sided exchange rate policy, followed by the home country, z is higher under a bilateral peg than a freely floating exchange rate, and, in the absence of velocity shocks, z is uniformly increasing in the degree of exchange rate intervention.

Proof:

Under the assumptions made, z is determined by

$$(2.4) \qquad \frac{(\lambda-1)(1+\psi)}{2\lambda}\left\{\left(\frac{\mu}{1+\mu}\right)^2 4\sigma_\gamma^2 + \left(\frac{\mu^2+1}{(1+\mu)^2}\right)\sigma_\chi^2\right\} = \Theta(z)$$

The first part of the proposition follows because the left hand side is higher when $\mu \to \infty$ (fixed exchange rate) than under $\mu = 0$ (flexible exchange rate), and so long as the equilibrium *z* is unique, then $\Theta(z)$ is increasing in *z*. The second part of the proposition follows because, without velocity shocks (i.e. $\sigma_\chi^2 = 0$), the left hand side of the above condition is always increasing in μ.

To see the result more intuitively, note that equilibrium price flexibility will be higher, whenever $\text{var}(m-\chi)$ is higher. But in order to keep the exchange rate from changing in face of relative demand shocks, the variance of *m* must rise (c.f equation (1.13)). At the same time, if we ignore relative demand shocks, under a floating exchange rate, $\text{var}(m-\chi)$ is equal to $\text{var}(\chi)$, while under a one sided pegged exchange rate, $\text{var}(m-\chi)$ is also equal to $\text{var}(\chi)$, since while the exchange rate peg offsets the impact of home velocity shocks on aggregate demand, it must adjust the money supply to prevent foreign velocity shocks affecting the exchange rate. Hence, when relative demand and velocity shocks are put together (and velocity shocks have equal variance), $\mathrm{var}(m-\chi)$ must be higher in a one sided peg than under a floating exchange rate.

This suggests that a policy of pegging the exchange rate should enhance the price flexibility of the economy, if the exchange rate rule takes the form of a one-sided or unilateral peg, and velocity shocks are equally volatile across countries. This is because the one-sided intervention rule will always increase the volatility of aggregate demand facing price setters. How does this compare to a bilateral pegged exchange rate? In this case, we have

Proposition 4

Under a bilateral exchange rate policy, z may be higher or lower with an exchange rate peg than a freely floating exchange, depending on the relative size of relative demand shocks and velocity shocks. In the absence of relative demand shocks, z is lower under a bilateral peg.

Proof: In this case, z is determined by

$$(2.5)\qquad \frac{(\lambda-1)(1+\psi)}{2\lambda}\left\{\left(\frac{\mu}{1+\mu}\right)^2\sigma_\gamma^2+\left(\frac{1+\mu+\frac{\mu^2}{2}}{(1+\mu)^2}\right)\sigma_\chi^2\right\}=\Theta(z)$$

When $\mu\to\infty$, the terms inside the curled brackets become $\sigma_\gamma^2+\frac{1}{2}\sigma_\chi^2$. From this condition, we see that, without relative demand shocks, the volatility of aggregate demand is strictly lower under a bilateral peg than under a freely floating exchange rate. Moreover, because each monetary authority cooperates in offsetting demand shocks, the volatility of aggregate demand specifically due to demand shocks is reduced, relative to that in a one-sided peg.

Intuitively, under a bilateral peg, in the case of velocity shocks alone, then $\text{var}(m-\chi)$ is lower because the home country has to adjust the domestic money supply according to the rule $m=-\frac{1}{2}(\hat{\chi}^*-\hat{\chi})$, rather than by $m=-(\hat{\chi}^*-\hat{\chi})$, as in the case of a one sided peg. Hence, for velocity shocks alone, home aggregate demand is less volatile with a bilateral peg than under a flexible exchange rate. Similarly, when faced with relative demand shocks, the home money supply must respond by $m=\hat{\gamma}$ under a bilateral peg, rather than $m=2\gamma$, as under a one sided peg.

Proposition 4 Corollary

There is always more price flexibility in a country that follows a one-sided peg than in a country that engages in a bilateral fixed exchange rate.

Proof: this is demonstrated in the previous discussion. The variance of nominal aggregate demand is always higher under a one sided peg.

Note that another difference between the two fixed exchange rate arrangements is that in the cooperative peg, z and z^* are equal. The cooperative peg affects price flexibility in both countries, whereas the one-sided peg affects price flexibility in the pegging country alone.

From Propositions 3 and 4, we see that the question of whether a pegged exchange rate enhances price flexibility depends principally on the nature of the shocks, as well as the nature of the exchange rate peg. When relative demand shocks are the principal source of exchange rate fluctuations, then an exchange rate peg will enhance price flexibility, and moreso in a country that adopts a one-sided peg. But when all exchange rate volatility is caused by velocity disturbances, an exchange rate peg will either leave price flexibility unchanged (in a one sided peg), or actually reduce overall price flexibility (in a bilateral peg).

So far, we have assumed that variance of velocity shocks is equal in the two countries. But imagine that $\sigma^2_{\chi*} < \sigma^2_{\chi}$. So the home country's χ shock is greater than that of the foreign country. We could think of this as a case where overall monetary/financial stability is higher in the foreign country, and the home country chooses a pegged exchange rate in order to `import' stability from abroad[7]. This has been a common rationale for fixed exchange rates in countries with a history of monetary instability, especially in Latin America. Looking again at condition (2.4), except allowing for different variances of χ and $\chi*$, we find that *z* is determined by the condition

$$\frac{(\lambda-1)(1+\psi)}{2\lambda}\left\{\left(\frac{\mu}{1+\mu}\right)^2 4\sigma^2_{\gamma}+\frac{\mu^2\sigma^2_{\chi*}+\sigma^2_{\chi}}{(1+\mu)^2}\right\}=\Theta(z)\,.$$

Upon inspection of this condition, it is no longer necessarily the case that the left hand side is increasing in μ. If σ^2_{χ} is sufficiently greater than $\sigma^2_{\chi*}$, then a unilateral peg can reduce overall aggregate demand volatility, and *reduce* the equilibrium degree of price flexibility. This is quite intuitive. If a country follows a policy of pegging its exchange rate to import monetary stability from abroad, then the overall instability of aggregate demand may fall rather than increase. As a result, equilibrium price flexibility will fall.

Output and Relative Price Stability Under Fixed Exchange Rates

Our results can be used to reappraise the conventional viewpoint about the stabilizing properties of floating exchange rates. Standard theory suggests that a freely floating exchange rate helps to stabilize output in response to relative demand shocks, because it allows for a greater adjustment of relative prices. Hence, the

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[7] In the model presented so far, χ does not strictly speaking represent instability of monetary policy. But we may re-interpret the model to think of χ as a shock to the monetary policy decision-making

volatility of output should be higher under an exchange rate peg than under a float, while the volatility of the terms of trade should be lower. In the particular model of this paper, home country output may be defined (in terms of deviations from the non-stochastic steady state) as

$$h = m - \hat{\chi} - p_h = \frac{(1-z)(m-\chi)}{(1-z\left(\frac{\lambda-1}{\lambda}\right))}.$$

Holding z constant, a unilaterally pegged exchange rate will always increase output volatility, when the volatility of velocity shocks is equal across countries. More generally, output volatility is higher (for fixed z) under a fixed exchange rate when the variance of m-χ is dominated by relative demand shocks. But with endogenous movements in z, there is a countervailing force. As z rises, a higher fraction of firms choose to adjust their price ex-post, and this tends to stabilize output. Hence, the indirect effects of an exchange rate peg, through endogenous price flexibility, run counter to the direct effects, through increasing the volatility of aggregate demand.

A similar conclusion may be obtained by looking at the terms of trade. We define the terms of trade as

$$\tau = s + p_f^* - p_h = s + \frac{\frac{z^*}{\lambda}(m^* - \hat{\chi}^*)}{(1-z^*\left(\frac{\lambda-1}{\lambda}\right))} - \frac{\frac{z}{\lambda}(m-\hat{\chi})}{(1-z\left(\frac{\lambda-1}{\lambda}\right))}.$$

With low z and z^* (when most prices are sticky), a fixed exchange rate prevents terms of trade adjustment. But, allowing z to respond to exchange rate policy, this conclusion no longer necessarily holds. As z and z^* go to unity, the terms of trade becomes $-2\hat{\gamma}$, the flexible price equilibrium response. Even though the direct effect of the exchange rate peg tends to reduce the possibility for relative price

process.

adjustment, the endogenous increase in price flexibility indirectly increases relative price adjustment.

While endogenous price flexibility might tend to lessen the impact of an exchange rate peg on output and terms of trade volatility, it would naturally be considered unlikely that this adjustment would reverse the direct effects of the policy change. But in the presence of strategic complementarities between price setting firms, this is not necessarily true. Because both the benefits of flexibility and the cost of flexibility are increasing in the measure of firms that choose flexibility, in principle it is possible that relatively modest changes in the benefits of flexibility have large changes in the total number of flexible price firms. Figure 2 and Table 1 provide a quantitative illustration of this. In this example the model is calibrated so that the volatility of both shocks is set to a standard deviation of 5 percent. The elasticity of substitution between categories of goods is set at 4. The cost of flexibility is chosen to be a very minor fraction of overall output. In the calibration, we choose the cost function so that if all households were investing in ex-post flexibility, the cost of this would be only 2 percent of GDP. These parameter choices are uncontroversial.

Now, given this calibration, we contrast a flexible exchange rate policy, where $\mu=0$, with a (unilateral) pegged exchange rate, where $\mu \to \infty$. Figure 2a illustrates the case of flexible exchange rates. In this case, under the calibration as described, the optimal degree of flexibility is quite small – only 11 percent all individuals choose ex-post flexibility (in both countries). However, note that with this calibration, both the VV and the CC loci are very flat (and positively sloped). Figure 2b shows the case of a unilateral peg. In this case, there is a dramatic rise in the measure of individuals choosing flexibility – now going to 89 percent.

What does this comparison imply for the volatility of GDP and the terms of trade? Table 2 shows volatilities under floating exchange rate, and under fixed exchange rates, when the measure of price setting firms is held constant at 11 percent (note that for the unilateral peg, z^* will stay at 0.11, since it is unaffected by home country exchange rate policy). As expected, the shift to a unilateral peg causes a dramatic rise in the standard deviation of output, going from 4.9 percent to 10.8 percent, and accompanying this, a large fall in terms of trade volatility; the standard deviation of the terms of trade falls from 12 percent to 0.3 percent. But when we take into account the endogenous response of price setters in the choice of ex-post flexibility, this conclusion is quite dramatically reversed. Under the unilateral peg, when z rises from 11 percent to 89 percent, the standard deviation of output after adjustment is 3.7 percent, and the standard deviation of the terms of trade is 7.4 percent. Hence, output volatility is even lower than under a flexible exchange rate! The message is clear – in the presence of significant strategic complementarity, even a relatively modest policy change can lead to a very substantial change in the degree of price flexibility. Slight difference in the calibration of the cost function for flexibility can make this conclusion even stronger – it is possible that a shift to a pegged exchange rate can shift the VV schedule above the CC schedule, so that all prices become flexible.

Table 2

	Output Variance	Terms of Trade Variance
Floating E. Rates (z=0.11)	4.9	12.2
One-sided Peg (z=0.11)	10.8	0.3
One-sided Peg (z=0.89)	3.7	7.4

Multiple Equilibrium

So far, we have abstracted from the possibility of multiple equilibrium. When the elasticity of substitution between commodities is high however, the possibility of multiple equilibrium arises, as we have discussed above. Figure 3 now illustrates the impact of a pegged exchange rate when we assume a high elasticity of substitution between commodities. Under a flexible exchange rate, there is a unique equilibrium, with almost all individuals choosing to set price in advance. But when the exchange rate is pegged (unilaterally), there are two stable equilibria – one with low price flexibility, and one with full price flexibility.

Therefore, while a floating exchange rate allows some relative price adjustment, the increase in aggregate demand volatility following a pegged exchange rate may lead to a substantial shift in the flexibility of the economy in responding to shocks. Precisely because a pegged exchange rate increases the volatility of the environment facing price setters, it allows for a self-fulfilling shift to an equilibrium where all prices are fully flexible[8].

Conclusions

This paper explores the impact of the exchange rate regime on the degree of price flexibility within a country. While we have focused only on one (`home') country, the results extend in an identical fashion to the foreign country. We find that if a country launches a fixed exchange rate against a trading partner on its own, it is likely to experience an increase in the flexibility of the local economy. But this result does not extend to the case of a cooperative fixed exchange rate. The model suggests therefore that there is no guarantee that a monetary union would enhance internal price flexibility, relative to a region of independent currencies with floating exchange rates.

One issue that we have not touched on is the welfare comparison across different exchange rate policy rules. In general, we might anticipate that welfare would be lower under a fixed exchange rate. In this model however, that conclusion may be incorrect, if a fixed exchange rate encourages greater price flexibility, but this would depend on the magnitude of the fixed costs incurred in order to obtain price flexibility.

There is even more difficulty in comparing welfare across regimes, in the framework of the present paper, however. This is because, due to the absence of risk sharing across countries, the flexible price equilibrium outcome is generally not Pareto efficient (see Obstfeld and Rogoff 2002 for discussion of this). As a result, it is not necessarily true that a flexible exchange rate dominates a fixed exchange rate in this model, in welfare terms, even though output volatility may be higher in the latter (see Devereux 2003 for discussion). Hence, the welfare comparison becomes clouded by other features of the model. As a result, it would be preferable to use a more general model in order to conduct a full welfare comparison across monetary policies within an environment of endogenous price flexibility to further research. Nevertheless, there is no reason to believe that the positive results of the present paper would not qualitatively hold in a more general setting.

[8] Note that in the intermediate equilibrium, the exchange rate peg actually reduces z. But following the usual reasoning, because this equilibrium is unstable we do not focus attention on it.

Appendix

To derivation of the second order approximation can be seen as follows. The utility to a household that does not adjust its price is[9];

$$V(P_h(i),P_h,P,X)=\ln\left(P_h(i)^{1-\lambda}P_h^{\lambda-1}\frac{M}{\chi P}\right)-\frac{\eta}{1+\psi}\left(P_h(i)^{-\lambda}P_h^{\lambda-1}\frac{M}{\chi}\right)^{1+\psi}$$

The utility to a household that does adjust is

$$\tilde{V}(P_h,P,X)=\ln\left(\left(\eta\hat{\lambda}\right)^{\frac{1}{1+\psi}}\left(\frac{P}{P_h}\right)^{\frac{1-\lambda}{\lambda}}\left(\frac{M}{\chi P}\right)^{\frac{1}{\lambda}}\right)-\frac{(\lambda-1)}{\lambda(1+\psi)}$$

Let $Z=\frac{M}{\chi P}$ and $Q=\frac{P}{P_h}$. Then we can approximate the difference between the utility of adjusting and not adjusting as

$$\tilde{V}-V\approx$$

$$0+\left[\frac{1}{\lambda}-1+\eta\bar{H}^{1+\psi}\right]\frac{Z-\bar{Z}}{\bar{Z}}+\left[\frac{1-\lambda}{\lambda}+\eta\bar{H}^{1+\psi}\right]\frac{Q-\bar{Q}}{\bar{Q}}-\left[(\lambda-1)-\eta\lambda\eta\bar{H}^{1+\psi}\right]\frac{P_h-\bar{P}_h}{\bar{P}_h}$$

$$-\frac{1}{2}\left[\frac{1}{\lambda}-1+\eta\bar{H}^{1+\psi}\right]\frac{(Z-\bar{Z})^2}{\bar{Z}^2}-\frac{1}{2}\left[\frac{1-\lambda}{\lambda}+\eta\bar{H}^{1+\psi}\right]\frac{(Q-\bar{Q})^2}{\bar{Q}^2}$$

$$+\frac{1}{2}\left[(\lambda-1)-\eta\lambda\eta\bar{H}^{1+\psi}\right]\frac{(P_h-\bar{P}_h)^2}{\bar{P}_h^2}$$

$$+\frac{\eta(1+\psi)\bar{H}^{1+\psi}}{2}\left(\frac{(Z-\bar{Z})^2}{\bar{Z}^2}+\lambda\frac{(Z-\bar{Z})}{\bar{Z}}\frac{P_h-\bar{P}_h}{\bar{P}_h}+\frac{P_h-\bar{P}_h}{\bar{P}_h}\frac{Q-\bar{Q}}{\bar{Q}}\right)$$

$$+\frac{\eta(1+\psi)\bar{H}^{1+\psi}}{2}\left(\frac{(Q-\bar{Q})^2}{\bar{Q}^2}+\lambda\frac{Q-\bar{Q}}{\bar{Q}}\frac{P_h-\bar{P}_h}{\bar{P}_h}+\frac{(Z-\bar{Z})}{\bar{Z}}\frac{(Q-\bar{Q})}{\bar{Q}}\right)$$

$$+\frac{\eta(1+\psi)\bar{H}^{1+\psi}}{2}\left(\lambda^2\frac{(P_h-\bar{P}_h)^2}{\bar{P}_h^2}+\lambda\frac{Q-\bar{Q}}{\bar{Q}}\frac{P_h-\bar{P}_h}{\bar{P}_h}+\frac{(Z-\bar{Z})}{\bar{Z}}\frac{(P_h-\bar{P}_h)}{\bar{P}_h}\right)$$

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[9] In this calculation, following Obstfeld and Rogoff (2002) and Corsetti and Pesenti (2001) we ignore the utility from real money balances, on the principle that it represents a very small component of

All the terms inside the square brackets are zero at the initial non-stochastic equilibrium. Then, taking expectations, using the fact that $\eta \bar{H}^{1+\psi} = \frac{1}{\hat{\lambda}}$, and that the sum of the last three terms inside the curved brackets, in expectations, is $\mathrm{var}(\lambda p_h + m - \chi)$, we arrive at condition (2.1).

overall welfare. Including this in the calculations would just introduce extra complicating terms, but would not change the overall tenor of the results.

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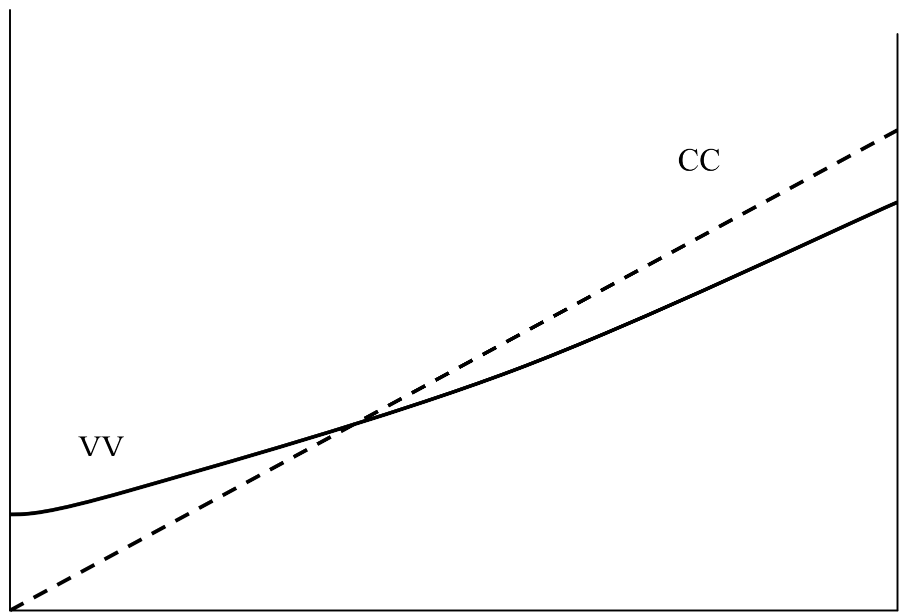

Figure 1a: Low λ, unique equilibrium

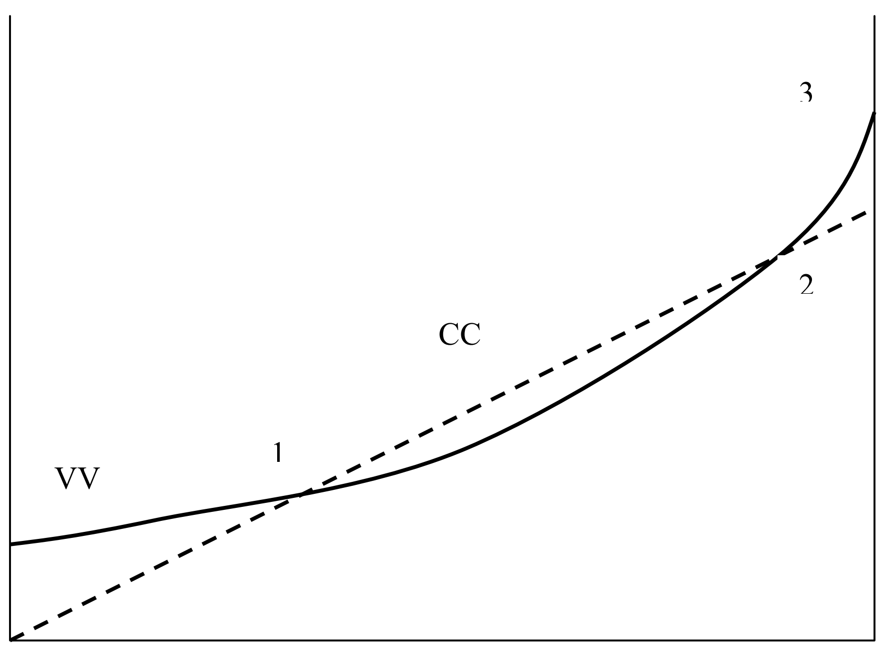

Figure 1b: High λ multiple equilibrium

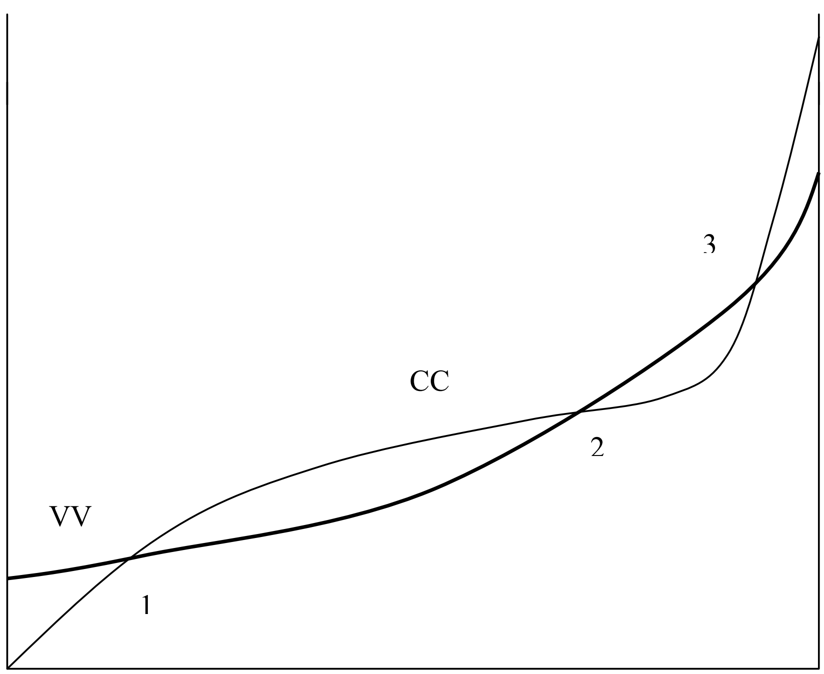

Figure 1c: Alternative cost function

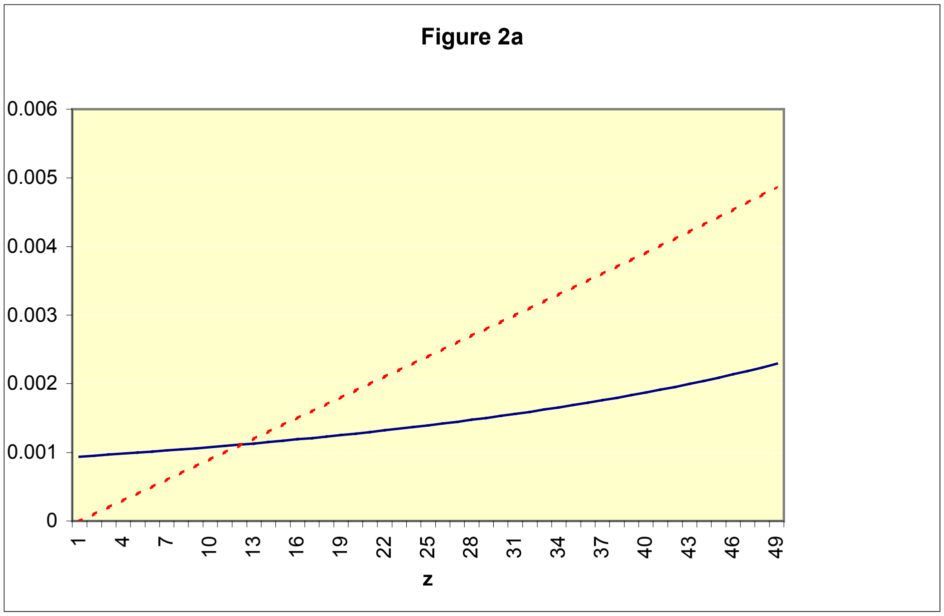
Figure 2a
0.006
0.005
0.004
0.003
0.002
0.001
0
1
4
7
10
13
16
19
22
25
28
31
34
37
40
43
46
49
z

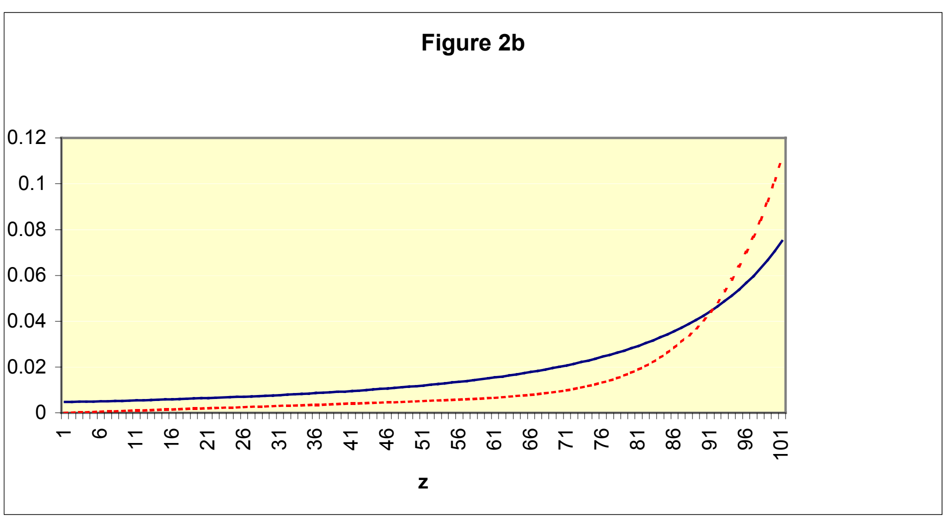
Figure 2b
0.12
0.1
0.08
0.06
0.04
0.02
0
1
6
11
16
21
26
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36
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86
91
96
101
z

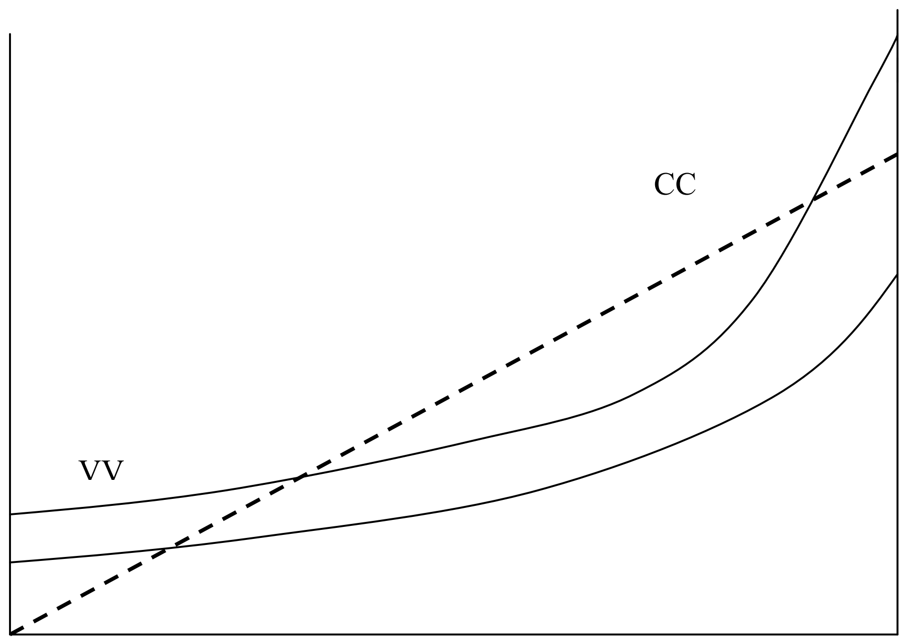

Figure 3: A pegged exchange rate can cause multiple equilibria