# Local Currency Pricing, Foreign Monetary Shocks and Exchange Rate Policy

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**Abstract**

The implications of local currency pricing (LCP) for monetary regime choice are analysed for a country facing foreign monetary shocks. In this analysis expenditure switching is potentially welfare reducing. This contrasts with the existing LCP literature, which focuses on productivity shocks and thus analyses a world where expenditure switching is welfare enhancing. This paper shows that, when home and foreign producers follow LCP, expenditure switching is absent and a floating rate is preferred by the home country. But when only home producers follow LCP, expenditure switching is present and a fixed rate can be welfare enhancing for the home country.

Keywords: monetary policy, foreign monetary shocks, expenditure switching, exchange rates, local currency pricing, reference currency.

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# 1 Introduction

Extensive empirical evidence suggests that producers engaged in international trade often set prices in the currency of buyers, i.e. they engage in local currency pricing (LCP).[1] This has prompted a lively literature examining optimal exchange rate and monetary policy in the context of LCP. This literature has, almost without exception, focused on models where the underlying source of uncertainty is shocks to productivity (or labour supply). This implies that exchange rate movements have a potentially beneficial role in directing consumer demand towards the country experiencing a positive productivity shock and away from the country experiencing low productivity. The expenditure switching role of exchange rates is therefore potentially welfare enhancing. The main point of debate in this literature is whether LCP, by breaking the short-term link between the nominal exchange rate and the prices faced by buyers, undermines the expenditure switching role of exchange rate movements and thus removes one of the benefits of exchange rate flexibility. Devereux and Engel (2003) in particular argue that, in the LCP case (where the exchange rate has no expenditure switching role), a fixed exchange rate is beneficial because it enhances consumption risk sharing.[2]

An alternative view of the exchange rate policy problem is that *monetary or financial market shocks* are an important source of movements in exchange rates. Such exchange rate movements, far from reallocating demand optimally, will in fact be the cause of misallocations of demand. In other words, in this view, the exchange rate is a *shock transmitter* rather than a *shock absorber*. The expenditure switching effect in this case is a source

[1] See, for instance, Engel (1999), Atkeson and Burstein (2008) and Burstein and Gopinath (2014) for broad discussion of empirical evidence on LCP. Recent important contributions to the empirical literature on LCP are Gopinath and Rigobon (2008), Goldberg and Campa (2010), Gopinath et al (2010) and Gopinath et al (2011).

[2] Devereux and Engel (2003) show that in the presence of LCP, exchange rate movements cause changes in the real exchange rate which undermine efficient consumption risk sharing. It is therefore optimal to stabilise the nominal exchange rate. There has been a number of counter-arguments to this point of view. For instance, Obstfeld (2002) shows that LCP in trade in final goods does not prevent expenditure switching as long as there is producer currency pricing (PCP) at the intermediate goods level, so a floating exchange rate is still better than a fixed rate. Duarte and Obstfeld (2008) show that even in the presence of LCP, exchange rate flexibility is necessary for optimal risk sharing even when there are non-traded consumption goods. In a more general model, Devereux and Engel (2007) show that optimal exchange rate flexibility depends on the trade-off between expenditure switching and risk sharing. Corsetti and Pesenti (2005), Engel (2011) and Sutherland (2005) present further analyses of optimal monetary policy in LCP models. Engel (2009) and Sutherland (2005) show that exchange rate variability is a potentially important factor in optimal monetary policy in certain circumstances. See Corsetti et al (2010) and Engel (2014) for recent surveys of the theoretical literature on optimal monetary policy in open economies.

of sub-optimal volatility in output and consumption. The idea that exchange rates are often substantially *misaligned* relative to real fundamentals is indeed a staple of the policy debate. The wide fluctuations in the value of the major currencies in the post Bretton Woods period have given rise to frequent calls for intervention to stabilise exchange rates. It is clear that there is a widespread view that fluctuations in nominal exchange rates of the magnitude of +/-50% in the space of a few years (as has been the case for the US dollar) are unlikely to be driven exclusively by optimal responses to relative productivity movements.

Clearly, by affecting the link between the nominal exchange rate and relative prices, LCP may have important implications for the way in which monetary and financial market shocks generate expenditure switching. This in turn may have a significant impact on the welfare performance of alternative exchange rate and monetary policy regimes. By focusing on productivity shocks, the current literature on LCP has largely overlooked this connection between monetary shocks, LCP and exchange rate regime choice. In this paper we aim to address this potentially important shortcoming of the current literature. We analyse the implications of LCP for monetary policy in an economy which faces exchange rate volatility arising from monetary shocks in a foreign country. The analysis focuses on optimal monetary policy for the home country in the face of these foreign monetary shocks. In our analysis, expenditure switching is potentially welfare reducing. This is in direct contrast to the Devereux and Engel (2003) analysis, which analyses the impact of LCP on regime choice in a world where expenditure switching may be welfare enhancing.

We analyse four possible combinations of producer currency pricing (or PCP, where producers set prices in their own currency) and LCP in a two-country model. There are two symmetric cases. One with both home and foreign producers following PCP (Case 1, in our analysis below). And one with both home and foreign producers following LCP (Case 2). There are also two asymmetric cases. One with home producers following PCP and foreign producers following LCP (Case 3). And one with home producers following LCP and foreign producers following PCP (Case 4).

In Case 1, where producers in both countries follow PCP, we show that the exchange rate volatility caused by foreign monetary shocks causes sub-optimal volatility in home-country output.[3] This creates an incentive for the home country to dampen movements in the exchange rate. However, in Case 2, where there is complete and symmetric LCP, we find that the expenditure switching effect is absent. This implies that exchange rate movements play no part in transmitting foreign monetary shocks to the home country. The incentive to stabilise the exchange rate is correspondingly reduced. In this case, floating

[3] A detailed analysis of this case is presented in Senay and Sutherland (2007a).

rate regimes are shown to be welfare superior to a fixed exchange rate. Notice that the presence of LCP in this case has an effect which is exactly opposite to that in the Devereux and Engel (2003) analysis, where LCP creates an incentive for exchange rate stabilisation.

These results are based on a case where producers in *both* countries follow local currency pricing.[4] The conclusions are somewhat different, however, if LCP is *asymmetric.* In Case 3, where home country producers adopt PCP while foreign producers adopt LCP, we find that the case for exchange rate *flexibility* is strengthened relative to the symmetric PCP case. But in the opposite case (Case 4), where home producers follow LCP and foreign producers follow PCP, the case for exchange rate *stabilisation* is strengthened. In fact, in this second asymmetric case, it is shown that a fixed rate can out-perform floating rate regimes in welfare terms.

It is shown therefore that LCP, when it arises in the particular asymmetric way represented by Case 4, can strengthen the argument for a fixed exchange rate. But the underlying reasons differ from those emphasised by Devereux and Engel (2003). It is the continued presence of expenditure switching in our Case 4 which is important, while in Devereux and Engel (2003) it is the absence of expenditure switching which creates the argument for exchange rate stabilisation.

The two asymmetric cases are particularly interesting because, for many countries, it is natural for both exports and imports to be priced in a reference currency, such as the US dollar. For instance, Tavlas (1997), Bekx (1998), Goldberg and Tille (2008), Gopinath and Rigobon (2008), Goldberg and Campa (2010) and Gopinath et al (2010) provide extensive evidence on the use of the US dollar as the currency most used for price setting in international trade. Case 4 corresponds to a world where the foreign currency is a reference currency (e.g. the US dollar). So the policy problem analysed can be interpreted as the choice faced by countries (other than the USA) in a world where trade is priced in US dollars and where US monetary shocks cause fluctuations in the value of the dollar. The conclusion is that such countries can benefit by stabilising (or even fixing) the value of their home currency against the dollar. This indeed corresponds to the monetary policy actually adopted by a wide range of emerging market countries. The first asymmetric case (Case 3) corresponds to a world where the home currency is a reference currency, while monetary shocks are occurring in a non-reference currency. The unsurprising conclusion, in this case, is that exchange rate flexibility is a useful way for the home country to insulate

[4] Our result for the symmetric LCP case closely resembles one of the cases considered by Bacchetta and van Wincoop (2000). Unlike much of the literature on monetary policy and LCP, Bacchetta and van Wincoop consider monetary shocks and in a potentially asymmetric policy analysis. They show that an asymmetric peg is inferior to a floating exchange rate. But, unlike this paper, they do not analyse asymmetric LCP.

itself from foreign monetary shocks.[5]

Devereux *et al* (2007) analyse optimal monetary policy in a world with a reference currency (i.e. a world with asymmetric LCP/PCP). They find that the reference currency country is indifferent to exchange rate volatility while non-reference currency countries place a high weight on exchange rate volatility in welfare. They focus on a Nash equilibrium in monetary policy setting and show that the reference currency country suffers a welfare loss from the reference status of its currency. Goldberg and Tille (2009) also analyse monetary policy in a world with a reference currency. As with much of the other literature on LCP, and in contrast to the analysis presented in this paper, these authors focus on optimal monetary policy in the face of productivity shocks.

The model we use is very standard. The main difference compared to others is the focus on monetary shocks. In itself, as a general proposition, it is not surprising that policy prescriptions change when the source of shocks changes. This is a well-known theoretical result. Our contribution is to analyse in detail how this works out in a standard model which has been widely used in the current literature. The simplicity of the model allows us to identify the specific transmission mechanisms of monetary shocks and show and describe intuitively how optimal policy depends on these mechanisms and the currency of price setting.

The paper proceeds as follows. Section 2 presents the details of the model, Section 3 describes and discusses the links between monetary policy and welfare, Section 4 presents the main discussion of alternative monetary policy regimes in the four cases outlined above, and Section 5 concludes.

[5] A further interesting question is prompted by our analysis. If firms could freely choose the currency in which to price goods, would the equilibrium display LCP in the home country and PCP in the foreign county, or vice versa? Gopinath et al (2010) provide evidence that endogenous choice of pricing currency is indeed a feature of the data. Our paper does not consider endogenous choice of invoicing currency, but Devereux, Engel and Storgaard (2004) offer some useful indicators of the likely effect. They show that the currency with the lowest variance of monetary shocks is likely to be chosen as the reference currency. In other words, in the model of the current paper, the home currency will be chosen as the reference currency. And thus exchange rate flexibility will be beneficial to the home country. However, there are other factors, not modelled by Devereux, Engel and Storgaard, which affect the choice of reference currency. The US dollar is clearly a major reference currency because of the size of the US economy and the liquidity and efficiency of US monetary and financial markets, and not because of the low variance of monetary shocks in the USA. The size and liquidity of the US monetary sector is thus likely to outweigh other factors in the choice of reference currency for small emerging market countries. Therefore, the case where home producers follow LCP and foreign producers follow PCP (our Case 4), with monetary shocks occurring in the foreign country, is likely to be relevant for many emerging market economies, despite the Devereux, Engel and Storgaard (2004) prediction.

# 2 The Model

We use a variant of the benchmark sticky-price general equilibrium model that follows the framework developed by Obstfeld and Rogoff (1995, 2002). The analysis focuses on the impact of foreign monetary shocks, which are the only source of stochastic shocks in the model. Four possible regimes for the home monetary authority considered.

The world consists of two equal-sized countries, the home country and the foreign country, and exists for only one period. Each country is populated by a unit mass of agents, with home agents indexed $h \in [0,1]$ and foreign agents indexed $f \in [0,1]$. The consumption basket is identical for all home and foreign agents and consists of all home and foreign produced goods. Each agent is a monopoly producer of a single differentiated product. All agents set prices before shocks occur and are contracted to meet demand at these pre-set prices. We consider both producer currency pricing (PCP) and local currency pricing (LCP).

The detailed structure of the home country is described below. The foreign country has an identical structure. Where appropriate, foreign real variables and foreign currency prices are indicated with an asterisk.

## 2.1 Preferences

The utility of representative home agent $h$ is

$$U(h) = E\left\{\log C(h) + \chi \log \frac{M(h)}{P} - \frac{K}{2}\left[y_H^2(h) + y_H^{*2}(h)\right]\right\} \tag{1}$$

where $\chi$ and $K$ are positive constants, $C$ is a consumption index defined across all home and foreign goods, $M$ denotes end-of-period nominal money holdings, $P$ is the consumer price index, $y_H(h)$ is the output of good $h$ for sale in the home country and $y_H^*(h)$ is the output of good $h$ for sale in the foreign country and $E$ is the expectations operator.[6]

The consumption index $C$ for home agents is

$$C = \left[\left(\frac{1}{2}\right)^{\frac{1}{\theta}} C_H^{\frac{\theta-1}{\theta}} + \left(\frac{1}{2}\right)^{\frac{1}{\theta}} C_F^{\frac{\theta-1}{\theta}}\right]^{\frac{\theta}{\theta-1}} \tag{2}$$

where $C_H$ and $C_F$ are Dixit-Stiglitz indices of home and foreign produced goods with elasticity between individual goods denoted $\phi$, where $\phi > 1$. The parameter $\theta$ is the

[6] Utility is assumed to be additively separable in $y_H(h)$ and $y_H^*(h)$. This greatly simplifies the algebra and provides a very simple and intuitive set of results. An alternative model, with non-additively separable utility in $y_H(h)$ and $y_H^*(h)$, delivers qualitatively the same conclusions but at the cost of greater complexity.

elasticity of substitution between home and foreign goods. In many papers in the related literature, this parameter is assumed to be unity. It will become apparent below that $\theta$ plays an key role in determining the strength of the expenditure switching effect and thus has important implications for the welfare ranking of monetary policy regimes.

The budget constraint of agent $h$ is

$$M(h) = M_0 + p_H(h)\, y_H(h) + S p_H^*(h)\, y_H^*(h) - PC(h) - T + PR(h) \tag{3}$$

where $M_0$ and $M(h)$ are initial and final money holdings, $T$ is a lump-sum government transfer, $p_H(h)$ is the price of home good $h$ for sale in the home market, $p_H^*(h)$ is the foreign currency price of home good $h$ for sale in the foreign market, $S$ is the nominal exchange rate (expressed as the home currency price of foreign currency) and $R(h)$ is the income from a portfolio of state contingent assets (to be described in more detail below in sub-section 2.3).

The government's budget constraint is: $M - M_0 + T = 0$. Changes in the money supply are assumed to enter and leave the economy via changes in lump-sum transfers.

The aggregate consumer price index for home agents is

$$P = \left[\frac{1}{2} P_H^{1-\theta} + \frac{1}{2} P_F^{1-\theta}\right]^{\frac{1}{1-\theta}} \tag{4}$$

where $P_H$ and $P_F$ are the price indices for home and foreign goods respectively.

Given the utility function and budget constraint just described, optimal home demands for home and foreign goods are

$$C_H = \frac{1}{2} C \left(\frac{P_H}{P}\right)^{-\theta}, \quad C_F = \frac{1}{2} C \left(\frac{P_F}{P}\right)^{-\theta} \tag{5}$$

The demand for home and foreign goods by foreign agents has an identical structure to the home demands. The total population of each country is normalised to unity. The total demands for goods are therefore equivalent to individual demands.

The aggregate output of home goods for sale in the home and foreign countries are respectively $Y_H$ and $Y_H^*$ and the corresponding outputs for the foreign country are $Y_F$ and $Y_F^*$. In equilibrium it follows that $Y_H = C_H$, $Y_F = C_F$, $Y_H^* = C_H^*$ and $Y_F^* = C_F^*$ where $C_H^*$ and $C_F^*$ are foreign country demands for home and foreign goods.

## 2.2 Price Setting

Agents set the prices of their output in advance of the realisation of shocks. The first-order conditions for price setting differ depending on whether producers engage in PCP or LCP.[7]

[7] We assume home and foreign goods markets are segmented (in the sense that separate prices can be set in home and foreign markets for all goods) in both PCP and LCP cases. Notice that the law of one price,

When home producers follow PCP (i.e. set prices in their own currency), the first-order condition for price setting imply

$$P_H = \frac{\phi}{\phi - 1} \frac{KE\left[Y_H^2\right]}{E\left[Y_H/(PC)\right]}, \quad P_H^* = \frac{\phi}{\phi - 1} \frac{KE\left[Y_H^{*2}\right]}{E\left[Y_H^*/(PC)\right]S} \tag{6}$$

where $P_H$ is the price of home goods for sale to home agents and $P_H^*$ is the price of home goods for sale to foreign agents (expressed in foreign currency). These expressions indicate that a form of risk premium arises in goods prices because agents face uncertainty over the level of work effort.

When home producers engage in LCP the first-order conditions for home and foreign prices are as follows

$$P_H = \frac{\phi}{\phi - 1} \frac{KE\left[Y_H^2\right]}{E\left[Y_H/(PC)\right]}, \quad P_H^* = \frac{\phi}{\phi - 1} \frac{KE\left[Y_H^{*2}\right]}{E\left[SY_H^*/(PC)\right]} \tag{7}$$

Note that the only difference between (7) and (6) is the way the exchange rate enters in the expression for $P_H^*$. In the PCP case, producers set the price of the home good in the foreign market in terms of home currency. The nominal exchange rate affects the foreign currency price, $P_H^*$, *after* the monetary shock is realised, so prices exhibit full exchange rate pass-through. In the LCP case home producers set the price of the home good in the foreign market in foreign currency *before* the monetary shock is realised and the exchange rate is determined. It is thus only *expectations* of the exchange rate which enter the expression for $P_H^*$ in (7). The actual realisation of the exchange rate has no impact on $P_H^*$, so there is no exchange rate pass-through.

Similar expressions can be derived for the prices of foreign goods, $P_F$ and $P_F^*$ in the PCP and LCP cases.

One of the monetary policy rules considered below is a regime which targets a measure of producer prices for the home economy. We define this producer price measure to be the price of home goods for sale in the home country, $P_H$. Because, in this model, all goods prices are pre-set (and thus do not vary in response to shocks), the 'price-targeting' regime is modelled in terms of the price level that producers would choose in a flexible price environment. This price level, denoted $P_H^V$ (where the superscript '$V$' indicates that this is a 'virtual' or 'notional' price level) is given by the expression for $P_H$ in (6) (or (7)) after removing the expectations operators from the right hand side, i.e.

$$P_H^V = \frac{\phi}{(\phi - 1)} K Y_H P C \tag{8}$$

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and thus purchasing power parity, does not hold even in the PCP case. Assuming non-segmented markets in the PCP case (so that the law of one price does hold in that case) makes no significant difference to the results reported below.

Price targeting is defined in terms of a target level for $P_H^V$.[8]

## 2.3 Financial Markets and Risk Sharing

When, as in the current model, shocks are asymmetric and the focus of interest is the policy choice and welfare of a single country, it is necessary explicitly to consider how policy choices affect asset prices and portfolio decisions. We assume that financial markets are sufficiently sophisticated to allow full sharing of consumption risks. This is achieved by assuming that trade takes place in equity shares in each country's real income. Thus a unit of the "home equity" pays a return proportional to $y$ where

$$y = (Y_H P_H/S + Y_H^* P_H^*)/P^*$$

and a unit of the "foreign equity" pays a return proportional to $y^*$ where

$$y^* = (Y_F P_F/S + Y_F^* P_F^*)/P^*$$

The portfolio returns for home and foreign agents are thus

$$R(h) = \zeta_H(h)(y - q_H)Q + \zeta_F(h)(y^* - q_F)Q \tag{9}$$

$$R^*(f) = \zeta_H^*(f)(y - q_H) + \zeta_F^*(f)(y^* - q_F) \tag{10}$$

where $\zeta_H(h)$ and $\zeta_F(h)$ are holdings of home agent $h$ of the home and foreign equities, $\zeta_H^*(f)$ and $\zeta_F^*(f)$ are the holdings of foreign agent $f$ of home and foreign equities, $q_H$ and $q_F$ are the unit prices of the home and foreign equities and $Q = P^*S/P$ is the real exchange rate.

It is important to note that (following Devereux and Engel, 2003), the payoffs from assets are assumed to be transferred between countries in terms of money. Transfers in terms of goods are ruled out. This implies that the equilibrium in asset markets does not ensure fully efficient risk sharing in the case of LCP. This is because households in the two countries value the portfolio payoffs in terms of the goods prices they face in their respective countries. In the LCP case, the law of one price does not hold so there will be distortions in relative valuations of the portfolio payoff across the two countries.

Asset trade is assumed to take place *after* the choice of policy regime. Agents can therefore insure themselves against the risk implied by a particular policy regime, but they can not insure themselves against the choice of regime itself.[9]

[8] Sutherland (2006) analyses monetary policy in a model where the population of producers is divided into flexible-price and fixed-price producers. The structure in the current paper can be interpreted as a limiting case where the proportion of flexible-price producers in such a framework tends to zero.

[9] See Senay and Sutherland (2007b) for a detailed discussion of the implications of the timing of asset trade for optimal monetary policy.

Asset market equilibrium implies the following relationship between consumption, asset prices and expected output levels in the two countries

$$\frac{C}{C^*} = \frac{q_H}{q_F} Q = \frac{E\left[\frac{y}{y+y^*}\right]}{E\left[\frac{y^*}{y+y^*}\right]} Q \tag{11}$$

The derivation of this expression is outlined in the Appendix. Notice that the real exchange rate, $Q$, enters this expression. Fluctuations in $Q$ in the LCP case reflect inefficient deviations from the law of one price. These cause deviations from efficient consumption risk sharing.

## 2.4 Money Demand and Supply

Optimal choice of money holdings implies

$$M/P = \chi C \tag{12}$$

The monetary authorities in each country set monetary policy in terms of the relevant national money supply. The money supply in the foreign country is assumed to be stochastic such that $\log M^*$ is symmetrically distributed over the interval $[-\epsilon, \epsilon]$ with $E[\log M^*] = 0$ and $Var[\log M^*] = \sigma^2$. These shocks may represent monetary policy errors on the part of the foreign monetary authority, or they may be interpreted as disturbances to foreign money demand, or as financial innovation shocks, which are not fully accommodated by money supply changes. The presence of such shocks clearly implies that the foreign central bank is not following an optimal monetary policy. Thus, the first-best policy, in terms of world aggregate welfare, would be a policy rule for the foreign central bank which entirely eliminates the monetary disturbances. However, the objective of the present paper is to analyse the home country monetary policy response when the global first-best policy rule is not being implemented by the foreign central bank. Thus, for the purposes of this exercise, the policy of the foreign central bank is taken to be a fixed and exogenous feature of the world economy.

We define home monetary policy in terms of a feedback rule of the following form

$$M = \bar{M} \left(M^*/\bar{M}^*\right)^{\delta} \tag{13}$$

The value of the policy feedback parameter, $\delta$, differs depending on the monetary regime under consideration. Four different regimes are considered: a fixed nominal exchange rate; money targeting; price targeting; and a welfare maximising monetary rule. In the fixed exchange rate regime, $\delta$ is chosen so that the exchange rate is maintained at a target level, $\bar{S}$. In the money targeting regime, $\delta$ is set to zero so that the home money supply is constant at $\bar{M}$. In the price targeting regime, $\delta$ is determined so that the virtual (or 'notional') producer-price level, $P_H^V$, is maintained at a target level, $\bar{P}_H^V$. And finally, optimal policy is defined to be the choice of $\delta$ which maximises home aggregate utility. The values of $\delta$ implied by each regime are stated below.[10]

# 3 Welfare

Aggregate welfare of home agents is measured using the following[11]

$$\Omega = E\left[\log C - \frac{K}{2}(Y_H^2 + Y_H^{*2})\right] \tag{14}$$

It is not possible to derive an exact solution to the model described above. A second-order approximation of the welfare expression is therefore derived. A summary of all the equations of the model (in both exact and approximated form) is provided in the Appendix. The Appendix also explains how a second-order accurate solution is obtained.[12]

A second-order approximation of the welfare measure is given by

$$\tilde{\Omega} = E\left\{\hat{C} - K\bar{Y}_H^2\left[\hat{Y}_H + \hat{Y}_H^2\right] - K\bar{Y}_H^{*2}\left[\hat{Y}_H^* + \hat{Y}_H^{*2}\right]\right\} + O\left(\epsilon^3\right) \tag{15}$$

where $\tilde{\Omega}$ is the deviation of the level of welfare from the non-stochastic equilibrium. Henceforth, a hat over a variable indicates a log deviation from the non-stochastic steady state and a bar indicates the value in the non-stochastic steady state. Notice that welfare expression (15) includes the first moments of consumption and output and the second moments of output components. Welfare is increasing in the expected level of consumption and decreasing in the expected level and variance of the components of output. Second-order accurate solutions for variances can be obtained from first-order accurate solutions for the relationships between endogenous variables and the shock variable. The analysis of volatility therefore involves working with a log-linearised (i.e. first-order approximated) version of the model. But a full second-order expression for welfare requires second-order accurate

[10]The target values of $\bar{M}$, $\bar{S}$ and $\bar{P}_H^V$ have no role other than to provide an anchor for nominal variables. The equilibrium level of nominal variables is irrelevant for aggregate utility and therefore has no implications for the analysis presented below.

[11]The utility of real balances is assumed to be small enough to be neglected.

[12]The approximation is taken around the non-stochastic equilibrium of the model, which is defined as the solution which results when $M^* = 1$ with $\sigma^2 = 0$. Note that, the only exogenous forcing variable in the model is the foreign money supply, $M^*$, so all log-deviations from the non-stochastic equilibrium are of the same order as the shocks, which (by assumption) are of maximum size $\epsilon$. When presenting an equation which is approximated up to order $n$ it is therefore possible to gather all terms of order higher than $n$ in a single term denoted $O\left(\epsilon^{n+1}\right)$.

solutions for *both* the first and second moments of variables. So, a full analysis of welfare involves working with a second-order approximation of the model.

In the non-stochastic equilibrium, $\bar{Y}_H$ and $\bar{Y}_H^*$ depend on the monopoly mark-up, $\phi/(\phi-1)$. A common practice in the related literature is to introduce a production subsidy to ensure that outputs are at their welfare maximising level. In all the cases which we will examine below it can be shown that $E[\hat{Y}_H] + E[\hat{Y}_H^2] = E[\hat{Y}_H^*] + E[\hat{Y}_H^{*2}] = 0$. The welfare results in this paper are thus independent of the value of $\bar{Y}_H$ and $\bar{Y}_H^*$ and are therefore independent of the monopoly distortion and any production subsidy. This also implies that welfare is effectively determined by $E[\hat{C}]$ alone, i.e. $\tilde{\Omega} = E[\hat{C}]$. This has the useful implication that welfare, as measured by $\tilde{\Omega}$, can be interpreted directly in terms of log-changes of consumption relative to its steady state level. Thus, in quantitative terms, $100 \times \tilde{\Omega}$ can be interpreted as directly equivalent to a percentage of steady state consumption.

## 3.1 Welfare and Output Volatility

Before analysing the individual monetary policy rules it is useful to trace and explain the main linkages between monetary policy and welfare. This will provide a framework to understand and explain the results presented in the next section. The Appendix shows that welfare, as defined in equation (15), can be re-written in a particularly simple and intuitive form. In Cases 1 and 4, where foreign producers are following PCP and the home producers are following either PCP (Case 1) or LCP (Case 4), welfare can be expressed as follows

$$\begin{aligned}\tilde{\Omega} &= \frac{1}{8}E\left\{-\frac{(5\theta-1)}{\theta}\hat{Y}_H^2 - \frac{(\theta-1)}{\theta}\hat{Y}_H^{*2}\right. \\ &\qquad \left. -\frac{(3\theta+1)}{\theta}\hat{Y}_F^2 + \frac{(\theta-1)}{\theta}\hat{Y}_F^{*2} + (\theta-1)\theta\hat{S}^2\right\} + O\left(\epsilon^3\right) \qquad (16)\end{aligned}$$

while in Cases 2 and 3, where the foreign producers are following LCP and the home producers are following either LCP (Case 2) or PCP (Case 3), welfare can be expressed in the form

$$\tilde{\Omega} = \frac{1}{8}E\left\{-\frac{(5\theta-1)}{\theta}\hat{Y}_H^2 - \frac{(\theta-1)}{\theta}\hat{Y}_H^{*2} - \frac{(3\theta+1)}{\theta}\hat{Y}_F^2 + \frac{(\theta-1)}{\theta}\hat{Y}_F^{*2}\right\} + O\left(\epsilon^3\right) \qquad (17)$$

Thus welfare can be written as a linear function of the variances of the components of output in each country, and in the case of equation (16) the variance of the exchange rate. So, monetary policy affects welfare via its effect on these individual variances.

The impact of monetary policy on the variances of $\hat{Y}_H$, $\hat{Y}_F$, $\hat{Y}_H^*$, $\hat{Y}_F^*$ and $\hat{S}$ will be described in more detail below, but first it is useful to understand why these variances affect welfare in the way shown in (16) and (17). As mentioned above, because $E[\hat{Y}_H] +$

$E[\hat{Y}_H^2] = E[\hat{Y}_H^*] + E[\hat{Y}_H^{*2}] = 0$, welfare depends directly (and only) on the expected level of consumption, $E[\hat{C}]$, so to explain (16) and (17) it is necessary first to understand how the variances of $\hat{Y}_H$, $\hat{Y}_F$, $\hat{Y}_H^*$, $\hat{Y}_F^*$ and $\hat{S}$ affect $E[\hat{C}]$.

The link between output variances and expected consumption operates via the impact of output variances on the optimal goods prices set by firms. This is shown most clearly in the first order conditions for price setting, equations (6) and (7). These equations show that an important determinant of the optimal price of a good is the variance of the output of that good. This reflects risk aversion on the part of producers. A higher output variance implies a higher optimal price. And, by definition, a higher optimal price implies a lower expected level of demand and thus a lower expected level of output of that good in equilibrium. There is thus a direct negative relationship between the variances of the output of each good and the expected level of output of that good, i.e. $E[\hat{Y}_H^2]$ has a negative effect on $E[\hat{Y}_H]$; $E[\hat{Y}_H^{*2}]$ has a negative effect on $E[\hat{Y}_H^*]$ and so on for the variances and expected levels of $\hat{Y}_F$ and $\hat{Y}_F^*$.

Having explained the link between output variances and expected output levels, it is now necessary to understand the link between expected output levels and the expected level of home consumption $E[\hat{C}]$ (which is equivalent to home aggregate welfare). The links between $E[\hat{Y}_H]$, $E[\hat{Y}_H^*]$, $E[\hat{Y}_F]$ and $E[\hat{Y}_F^*]$ and expected consumption, $E[\hat{C}]$, depend on three offsetting effects which vary in strength across the different types of good.

The first effect is an *aggregate resource effect*. An increase in the output of any type of good increases the aggregate resources available for consumption in the world. The second effect is a *terms of trade effect*. An increase in the output of goods produced in the home country (for either home or foreign consumption) depresses the home terms of trade. The strength of this effect depends on $\theta$, the international trade elasticity. If $\theta$ is greater than unity, an increase in the output of home goods has a relatively small impact on the terms of trade, so the relative income of the home country increases. This allows the home country to expand consumption at the expense of the foreign country. The third effect is a *real exchange rate effect*. An increase in the output of goods consumed by the home country reduces the relative price of the home consumption basket and thus again allows the home country to increase consumption at the expense of the foreign country.[13]

In the case of goods produced in the home country and consumed in the home country, all three of these effects work in the same direction (at least when $\theta > 1$). So a reduction in the variance of $\hat{Y}_H$ raises $E[\hat{Y}_H]$ and raises $E[\hat{C}]$, hence the negative coefficient on $E[\hat{Y}_H^2]$ in (16) and (17). In the case of goods produced in home country and consumed in the foreign

[13] Note that price discrimination between home and foreign markets implies that purchasing power parity does not hold, even when producers follow PCP. This implies that the *real exchange rate effect* is present in all permutations of LCP and PCP.

country, the terms of trade and real exchange rate effects work in opposite directions (when $\theta > 1$). The terms of trade effect, however, appears to dominate, so that a rise in $E[\hat{Y}_H^*]$ increases home income and raises $E[\hat{C}]$. Hence the negative coefficient on $E[\hat{Y}_H^{*2}]$ in (16) and (17) when $\theta > 1$. In the case of foreign produced goods, the terms of trade and real exchange rate effects again work in opposite directions (when $\theta > 1$). For foreign produced goods for home consumption, the net effect implies a negative coefficient on $E[\hat{Y}_F^2]$ in (16) and (17), i.e. a rise in $E[\hat{Y}_F]$ increases $E[\hat{C}]$. While for foreign produced goods for foreign consumption, the net effect is a positive coefficient on $E[\hat{Y}_F^{*2}]$ in (16) and (17), i.e. a reduction in $E[\hat{Y}_F^*]$ increases $E[\hat{C}]$. This last effect arises because a reduction in $E[\hat{Y}_F^*]$ raises the cost of the foreign consumption basket and therefore allows home consumption to increase relative to foreign consumption.[14]

This completes the explanation of the link between output variances and welfare. Equation (16), however, shows that, when foreign producers follow PCP, the variance of the exchange rate also enters the welfare expression. This effect arises from a combination of a number of small and offsetting effects which have no clear economic interpretation. This effect is positive when $\theta > 1$. Thus exchange rate volatility appears to have a positive effect on welfare for $\theta > 1$. But note that exchange rate volatility has an additional indirect effect on welfare via its impact on the variances of $\hat{Y}_H$, $\hat{Y}_F$, $\hat{Y}_H^*$ and $\hat{Y}_F^*$. It is these indirect effects that dominate the relative performance of the different policy regimes analysed below.

## 3.2 Monetary Policy and Output Volatility

The previous sub-section explained welfare in terms of the volatility of $\hat{Y}_H$, $\hat{Y}_F$, $\hat{Y}_H^*$, $\hat{Y}_F^*$ and $\hat{S}$. This explains one part of the link between monetary policy and welfare. It is now necessary to explain the second part of the link, i.e. the link between home monetary policy and the volatility of $\hat{Y}_H$, $\hat{Y}_F$, $\hat{Y}_H^*$, $\hat{Y}_F^*$ and $\hat{S}$. When considering the impact of monetary policy on volatility it is sufficient to look at first-order accurate solutions to the model.[15]

A first-order expansion of equation (11) shows that risk sharing implies the following relationship between realised consumption levels in the two countries: $\hat{C} - \hat{C}^* = \hat{S} + \hat{P}^* - \hat{P} + O(\epsilon^2)$. When combined with the expressions for home and foreign money demand (which imply $\hat{M} = \hat{P} + \hat{C}$ and $\hat{M}^* = \hat{P}^* + \hat{C}^*$), the following expression for the exchange

[14] Clearly, the sign of the terms of trade effect depends on the value of $\theta$. When $\theta < 1$ an increase in the volume of output can lead to a fall in the value of home income. This reverses the sign of the coefficients on $E[\hat{Y}_H^{*2}]$ and $E[\hat{Y}_F^{*2}]$ in the welfare expressions.

[15] Terms of order two and higher in expressions for realised values become terms of order three and higher in expressions for variances. Higher order terms in expressions for realised values are therefore irrelevant for the second-order accurate analysis of welfare.

rate is obtained

$$\hat{S} = \hat{M} - \hat{M}^* + O\left(\epsilon^2\right) \tag{18}$$

Thus the nominal exchange rate depends on *relative monetary policy*, i.e. the difference between the home money supply and the foreign money supply. This is one part of the link between monetary policy and the volatility of $\hat{Y}_H$, $\hat{Y}_F$, $\hat{Y}_H^*$ and $\hat{Y}_F^*$.

Using (5) and the corresponding expressions for the foreign country, first-order approximations for home and foreign aggregate output levels can be written as follows

$$\hat{Y}_H = \hat{C} - \theta(\hat{P}_H - \hat{P}) + O\left(\epsilon^2\right), \qquad \hat{Y}_H^* = \hat{C}^* - \theta(\hat{P}_H^* - \hat{P}^*) + O\left(\epsilon^2\right) \tag{19}$$

$$\hat{Y}_F = \hat{C} - \theta(\hat{P}_F - \hat{P}) + O\left(\epsilon^2\right), \qquad \hat{Y}_F^* = \hat{C}^* - \theta(\hat{P}_F^* - \hat{P}^*) + O\left(\epsilon^2\right) \tag{20}$$

These equations show that output levels depend on aggregate consumption in the relevant country and a relative price term. Making use of first-order approximations of $\hat{P}$ and $\hat{P}^*$ (i.e. (4) and its foreign counterpart) and the expressions for money demand (i.e. (12) and its foreign counterpart) it is possible to rewrite (19) and (20) as follows

$$\hat{Y}_H = \hat{M} - \frac{\theta+1}{2}\hat{P}_H + \frac{\theta-1}{2}\hat{P}_F + O\left(\epsilon^2\right), \qquad \hat{Y}_H^* = \hat{M}^* - \frac{\theta+1}{2}\hat{P}_H^* + \frac{\theta-1}{2}\hat{P}_F^* + O\left(\epsilon^2\right) \tag{21}$$

$$\hat{Y}_F = \hat{M} + \frac{\theta-1}{2}\hat{P}_H - \frac{\theta+1}{2}\hat{P}_F + O\left(\epsilon^2\right), \qquad \hat{Y}_F^* = \hat{M}^* + \frac{\theta-1}{2}\hat{P}_H^* - \frac{\theta+1}{2}\hat{P}_F^* + O\left(\epsilon^2\right) \tag{22}$$

Furthermore, it follows from the first-order conditions for price setting that $\hat{P}_H = 0$ and $\hat{P}_F^* = 0$. So

$$\hat{Y}_H = \hat{M} + \frac{\theta-1}{2}\hat{P}_F + O\left(\epsilon^2\right), \qquad \hat{Y}_H^* = \hat{M}^* - \frac{\theta+1}{2}\hat{P}_H^* + O\left(\epsilon^2\right) \tag{23}$$

$$\hat{Y}_F = \hat{M} - \frac{\theta+1}{2}\hat{P}_F + O\left(\epsilon^2\right), \qquad \hat{Y}_F^* = \hat{M}^* + \frac{\theta-1}{2}\hat{P}_H^* + O\left(\epsilon^2\right) \tag{24}$$

Expressions (23) and (24) show that output levels depend on the money supply and $\hat{P}_F$ (the price of foreign goods in the home market) and $\hat{P}_H^*$ (the price of home goods in the foreign market). The first-order behaviour of $\hat{P}_H^*$ and $\hat{P}_F$ in turn depend on whether producers are following PCP or LCP pricing. If home producers are following PCP then $\hat{P}_H^* = -\hat{S}$, while in the LCP case $\hat{P}_H^* = 0$. Likewise if foreign producers are following PCP then $\hat{P}_F = \hat{S}$, while the LCP case implies $\hat{P}_F = 0$. The links between monetary policy and output therefore depend on the configuration of PCP and LCP across the two countries. The expressions for output levels are summarised in Table 1. The table shows the expressions for output levels (after substituting for the exchange rate using $\hat{S} = \hat{M} - \hat{M}^*$) for the four permutations of PCP and LCP across the two countries.

The expressions in Table 1 show that monetary policy has potentially two effects on output levels, one via the impact of home money on the world aggregate money supply,

Table 1: Output Expressions in Cases 1-4

**Case 1 (Home PCP, Foreign PCP)**

| | |
|---|---|
| $\hat{Y}_H = \frac{1}{2}(\hat{M} + \hat{M}^*) + \frac{\theta}{2}(\hat{M} - \hat{M}^*)$ | $\hat{Y}_H^* = \frac{1}{2}(\hat{M} + \hat{M}^*) + \frac{\theta}{2}(\hat{M} - \hat{M}^*)$ |
| $\hat{Y}_F = \frac{1}{2}(\hat{M} + \hat{M}^*) - \frac{\theta}{2}(\hat{M} - \hat{M}^*)$ | $\hat{Y}_F^* = \frac{1}{2}(\hat{M} + \hat{M}^*) - \frac{\theta}{2}(\hat{M} - \hat{M}^*)$ |

**Case 2 (Home LCP, Foreign LCP)**

| | |
|---|---|
| $\hat{Y}_H = \hat{M}$ | $\hat{Y}_H^* = \hat{M}^*$ |
| $\hat{Y}_F = \hat{M}$ | $\hat{Y}_F^* = \hat{M}^*$ |

**Case 3 (Home PCP, Foreign LCP)**

| | |
|---|---|
| $\hat{Y}_H = \hat{M}$ | $\hat{Y}_H^* = \frac{1}{2}(\hat{M} + \hat{M}^*) + \frac{\theta}{2}(\hat{M} - \hat{M}^*)$ |
| $\hat{Y}_F = \hat{M}$ | $\hat{Y}_F^* = \frac{1}{2}(\hat{M} + \hat{M}^*) - \frac{\theta}{2}(\hat{M} - \hat{M}^*)$ |

**Case 4 (Home LCP, Foreign PCP)**

| | |
|---|---|
| $\hat{Y}_H = \frac{1}{2}(\hat{M} + \hat{M}^*) + \frac{\theta}{2}(\hat{M} - \hat{M}^*)$ | $\hat{Y}_H^* = \hat{M}^*$ |
| $\hat{Y}_F = \frac{1}{2}(\hat{M} + \hat{M}^*) - \frac{\theta}{2}(\hat{M} - \hat{M}^*)$ | $\hat{Y}_F^* = \hat{M}^*$ |

$(\hat{M} + \hat{M}^*)$, and one via the impact of home money on relative money supplies, $(\hat{M} - \hat{M}^*)$. The first effect arises because, for given price levels, monetary policy affects home and foreign aggregate consumption, $C$ and $C^*$, directly via money market equilibrium. The second effect arises because monetary policy affects relative goods prices via the nominal exchange rate, $S$ (as shown in (18)). But the magnitude of this second effect depends on the degree of exchange rate pass-through, and thus differs in the PCP and LCP cases. The relative price effect also depends on the international trade elasticity, $\theta$. The relative importance of $(\hat{M} + \hat{M}^*)$ and $(\hat{M} - \hat{M}^*)$ in $\hat{Y}_H$, $\hat{Y}_F$, $\hat{Y}_H^*$ and $\hat{Y}_F^*$ thus depends jointly on the value of $\theta$ *and* the form of price setting. The larger the value of $\theta$ (i.e. the stronger the expenditure switching effect) the more important is volatility in $S$ and thus the more important is $(\hat{M} - \hat{M}^*)$. But this effect only arises in the PCP case. In the LCP case, there is no pass-through from exchange rate changes to prices.

Given exogenous shocks to $M^*$, a policy which stabilises $(\hat{M} + \hat{M}^*)$ will necessarily destabilise $(\hat{M} - \hat{M}^*)$ and vice versa. The home monetary authority therefore faces a trade-off between stabilising $(\hat{M} + \hat{M}^*)$ and $(\hat{M} - \hat{M}^*)$. The terms of this trade-off will depend on the form of price setting, PCP versus LCP, and on the value of $\theta$. The balance between these different effects clearly has important implications for the relative welfare

Table 2: Policy feedback parameter, welfare and exchange rate volatility in Case 1

| | Fixed rate | Money targeting | Price targeting | Optimal policy |
|---|---|---|---|---|
| $\delta$ | 1 | 0 | $\frac{\theta-1}{\theta+3}$ | $\frac{\theta^2+\theta-2}{\theta(\theta+3)}$ |
| $\tilde{\Omega}$ | $-\sigma^2$ | $-\frac{1}{8}\left[\theta^2-\theta+4\right]\sigma^2$ | $-\left(\frac{\theta+1}{\theta+3}\right)\sigma^2$ | $-\left(\frac{\theta^2+4\theta-1}{2\theta(\theta+3)}\right)\sigma^2$ |
| $E\left[\hat{S}^2\right]$ | 0 | $\sigma^2$ | $\left(\frac{4}{\theta+3}\right)^2\sigma^2$ | $\left(\frac{2(\theta+1)}{\theta(\theta+3)}\right)^2\sigma^2$ |

performance of the different policy regimes. This will become clear as the results are described for the four different permutations of LCP and PCP in Cases 1 to 4.

# 4 Results

The results are now presented for the four cases outlined in the introduction. In Case 1 both home and foreign producers follow PCP.[16] In Case 2 both home and foreign producers follow LCP. Cases 3 and 4 are asymmetric. In Case 3 home producers follow PCP and foreign producers follow LCP. And in Case 4 home producers follow LCP and foreign producers follow PCP.

## 4.1 Case 1: Home and Foreign Producers Follow PCP

Table 2 presents a comparison between the four monetary policy regimes when both home and foreign producers follow PCP. These results are also illustrated in Figures 1, 2 and 3 where $\delta$ (the policy feedback parameter), $\tilde{\Omega}$ (welfare) and the standard deviation of $\hat{S}$ are plotted for the four policy regimes for a range of values of $\theta$.[17] The results shown in Table 2 and Figures 1, 2 and 3 correspond to the results presented in our previous analysis (Senay and Sutherland, 2007a).[18]

First consider a comparison between money targeting and a fixed nominal exchange

[16] A detailed analysis of Case 1 is presented in Senay and Sutherland (2007a).

[17] For the purpose of illustration these figures, and all subsequent figures, are based on $\sigma = 0.1$. The vertical axis in Figure 2 plots welfare in terms of $100 \times \tilde{\Omega}$. This quantity can be interpreted as a percentage of steady state consumption. Subsequent welfare plots can also be interpreted in these terms.

[18] There are minor differences compared to Senay and Sutherland (2007a) because our previous analysis was based on a model where utility was not additively separable in $\hat{Y}_H$ and $\hat{Y}_H^*$. These small differences do not change the qualitative nature of the results.

Figure 1: $\delta$ in Case 1

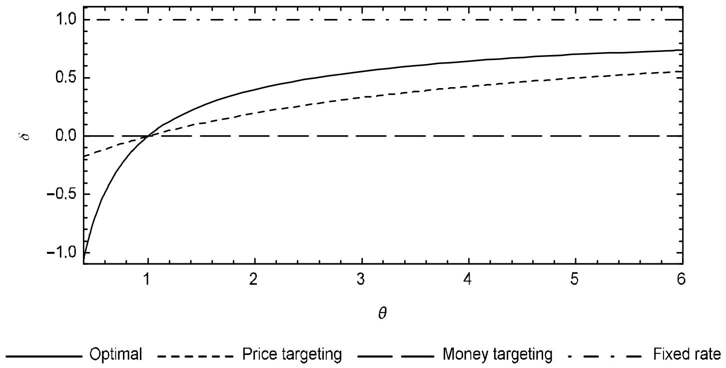



Figure 2: Welfare in Case 1

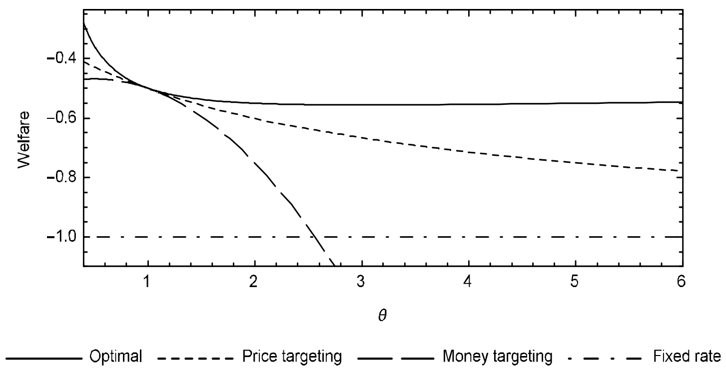
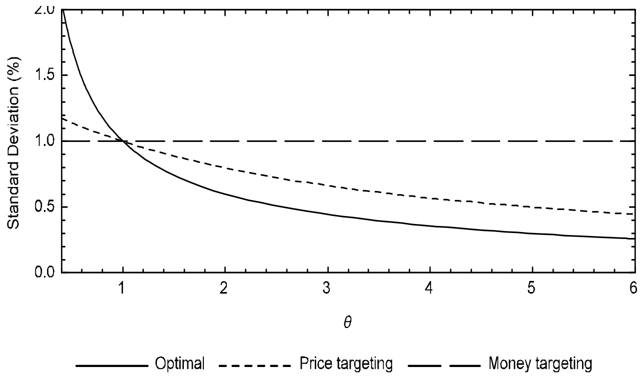



Figure 3: Exchange rate variability in Case 1



rate. In terms of the policy rule (13), monetary targeting clearly implies $\delta = 0$, while equation (18) shows that a fixed nominal exchange rate requires $\delta = 1$. The welfare comparison in Table 2 and Figure 2 shows that, for low values of $\theta$ money targeting delivers higher welfare than a fixed rate, while the opposite is the case for higher values of $\theta$. This can be easily understood by considering the welfare function in (16) and the expressions for the components of output given in Table 1. The main determinants of welfare are the variances of $\hat{Y}_H$ and $\hat{Y}_H^*$. The expressions in Table 1 show that in Case 1 the variances of both $\hat{Y}_H$ and $\hat{Y}_H^*$ are heavily influenced by the trade-off between aggregate money, $(\hat{M} + \hat{M}^*)$, and relative money, $(\hat{M} - \hat{M}^*)$.

Relative monetary policy, $(\hat{M} - \hat{M}^*)$, clearly becomes more important as $\theta$ increases, i.e. as the international trade elasticity rises. Money targeting is good for stabilising $(\hat{M} + \hat{M}^*)$, while a fixed rate is good for stabilising $(\hat{M} - \hat{M}^*)$. Thus money targeting is the better policy when $(\hat{M} - \hat{M}^*)$ is relatively less important for output determination, i.e. when $\theta$ is low, while a fixed rate is better when $(\hat{M} - \hat{M}^*)$ is relatively more important, i.e. when $\theta$ is high.

Now consider the welfare performance of price targeting (defined in terms of targeting $P_H^V$). For $\theta > 1$, Table 2 shows that price targeting implies a value of $\delta$ between zero and unity. Thus price targeting can be regarded as a compromise between monetary targeting and a fixed rate. Figure 2 shows that price targeting delivers higher welfare than both a fixed rate and money targeting for all values of $\theta$. This higher welfare performance arises because price targeting offers a compromise between stabilising $(\hat{M} + \hat{M}^*)$ and stabilising $(\hat{M} - \hat{M}^*)$. Price targeting is thus more successful at stabilising home output than either a fixed rate or money targeting. Notice that, as $\theta$ rises, so that exchange rate volatility becomes more important in determining output volatility, price targeting tends to imply more exchange rate stabilisation.

While price targeting is a good compromise between a fixed rate and money targeting, Table 2 shows that price targeting is not equivalent to the fully optimal policy. The fully optimal policy rule is given by choosing the value of $\delta$ to maximise home welfare. The implied optimal value of $\delta$ is shown in Table 2. For $\theta > 1$ it is clear that this value of $\delta$ is again between zero and unity, so optimal policy is a compromise between a fixed rate and money targeting. Figure 3 shows that price targeting is a reasonably good approximation for optimal policy, but optimal policy (for $\theta > 1$) implies slightly more exchange rate stabilisation than price targeting.[19]

[19] Notice that when $\theta < 1$ optimal policy implies higher exchange rate volatility than the other regimes. As previously explained, when $\theta < 1$, an increase in home output reduces home income. This reverses the welfare impact of exchange rate volatility. When $\theta < 1$, higher exchange rate volatility reduces home output and increases home income.

A useful point of comparison in the existing literature is the analysis of Benigno and Benigno (2003) who show that price targeting is the optimal coordinated and Nash equilibrium policy in a two-country model with PCP and shocks to productivity. Benigno and Benigno (2003) assume a unit elasticity between home and foreign goods ($\theta = 1$), but the optimality of price targeting in a coordinated equilibrium continues to hold in their framework for $\theta$ different from unity. This contrasts with our finding that price targeting is not fully optimal in the face of foreign monetary shocks when $\theta$ differs from unity.

## 4.2 Case 2: Home and Foreign Producers Follow LCP

Now consider Case 2, where both home and foreign producers follow LCP. Table 3 presents a comparison between the four monetary regimes for Case 2.

It is immediately clear that monetary targeting, price targeting and optimal policy are all identical in this case. They all imply $\delta = 0$ and they all deliver higher welfare than a fixed nominal exchange rate. The explanation for this ranking of regimes is simple to understand in terms of the output equations in Table 1 and the welfare expression (17). These equations show that $\hat{Y}_H$ and $\hat{Y}_F$ depend only on $\hat{M}$ and that $\hat{Y}^*_H$ and $\hat{Y}^*_F$ depend only on $\hat{M}^*$. Home monetary policy has no impact on $\hat{Y}^*_H$ and $\hat{Y}^*_F$ so there is no scope for monetary policy to stabilise these components of output. The only role for home monetary policy is thus to stabilise $\hat{Y}_H$ and $\hat{Y}_F$ and this can be achieved by a completely passive monetary regime, i.e. monetary targeting. This policy also completely stabilises $\hat{P} + \hat{C}$ and thus (given stabilisation of $\hat{Y}_H$) delivers perfect stabilisation of $\hat{P}^V_H$, as required by price targeting.

A fixed rate regime, however, is clearly sub-optimal because it requires home monetary policy to match the foreign money shocks. This causes unnecessary, and welfare reducing, volatility in $\hat{Y}_H$ and $\hat{Y}_F$.

The underlying reason for the contrast with Case 1 is the complete absence of the expenditure switching effect of exchange rate changes when both home and foreign producers follow LCP. Symmetric LCP implies that exchange rate changes have no impact on the relative prices faced by consumers in the short run. Nominal exchange rate volatility is therefore irrelevant for output determination and welfare. The incentive to stabilise the exchange rate is correspondingly reduced. An obvious corollary of this is that the international trade elasticity, $\theta$, is irrelevant to the welfare comparison between policy regimes.

Notice that the presence of LCP in this model has an effect which is exactly opposite to that in the Devereux and Engel (2003) analysis, where LCP creates an incentive for exchange rate stabilisation. In the Devereux and Engel (2003) model the impact of exchange rate volatility on consumption risk sharing is strong enough on its own to make a fixed rate

Table 3: Policy feedback parameter, welfare and exchange rate volatility in Case 2

| | Fixed rate | Money targeting | Price targeting | Optimal policy |
|---|---|---|---|---|
| $\delta$ | 1 | 0 | 0 | 0 |
| $\tilde{\Omega}$ | $-\sigma^2$ | 0 | 0 | 0 |
| $E\left[\hat{S}^2\right]$ | 0 | $\sigma^2$ | $\sigma^2$ | $\sigma^2$ |

Table 4: Policy feedback parameter, welfare and exchange rate volatility in Case 3

| | Fixed rate | Money targeting | Price targeting | Optimal policy |
|---|---|---|---|---|
| $\delta$ | 1 | 0 | 0 | 0 |
| $\tilde{\Omega}$ | $-\sigma^2$ | $\frac{(\theta-1)}{8}\sigma^2$ | $\frac{(\theta-1)}{8}\sigma^2$ | $\frac{(\theta-1)}{8}\sigma^2$ |
| $E\left[\hat{S}^2\right]$ | 0 | $\sigma^2$ | $\sigma^2$ | $\sigma^2$ |

optimal. This effect does not arise in the model analysed here because a fixed exchange rate transfers consumption risk from the foreign country to the home country. This may be welfare improving for the foreign country and even may be welfare improving for the world as a whole (measured in terms of the aggregate of home and foreign utility) but it is not welfare improving for the home country.

### 4.3 Case 3: Home Producers Follow PCP, Foreign Producers Follow LCP

Table 4 and Figures 4, 5 and 6 present a comparison between the four monetary policy regimes in Case 3, where home producers follow PCP and foreign producers follow LCP. This corresponds to a world where the home currency is an international reference currency, while monetary shocks are occurring in a non-reference currency. So the home country can be thought of as the USA, for instance, while monetary shocks may be thought of as occurring outside the USA.

Table 4 shows that, again, money targeting, price targeting and optimal policy are all

Figure 4: $\delta$ in Case 3


Figure 5: Welfare in Case 3

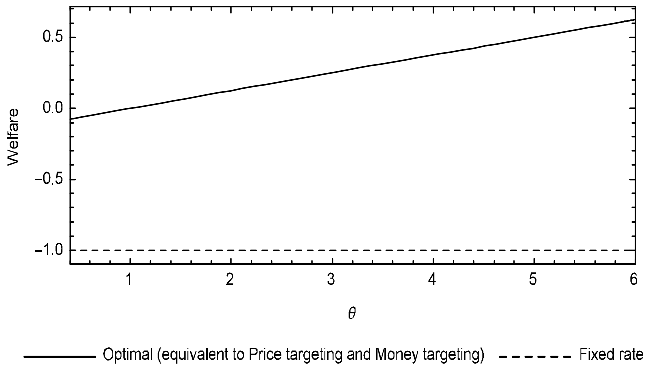
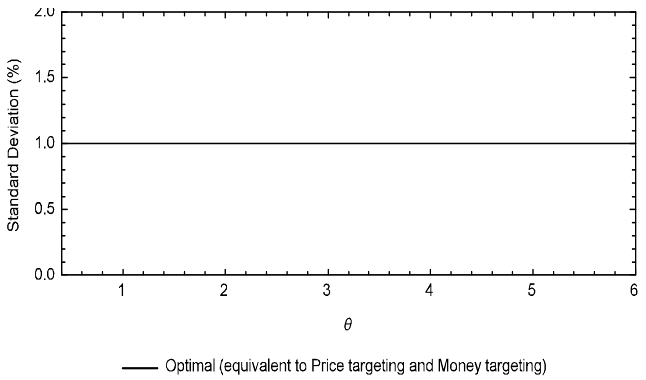



Figure 6: Exchange rate variability in Case 3



identical. In all these cases the value of $\delta$ is zero. As in Case 2, these regimes yield higher welfare than a fixed exchange rate.

This ranking of policy regimes is again easily explained with reference to the output expressions given in Table 1 and the welfare expression (17). In Case 3 these expressions show that $\hat{Y}_H$ and $\hat{Y}_F$ depend only on $\hat{M}$. $\hat{Y}_H$ and $\hat{Y}_F$ are the outputs of goods which the home country consumes so, as discussed in Section 3.1, the variances of $\hat{Y}_H$ and $\hat{Y}_F$ are particularly significant in the determination of home welfare. Clearly, therefore, the stabilisation of $\hat{Y}_H$ and $\hat{Y}_F$ has strong welfare benefits. This has a close parallel to the results just discussed for Case 2. However, unlike Case 2, $\hat{Y}_H^*$ and $\hat{Y}_F^*$ are not independent of home monetary policy. Nevertheless, the variances of $\hat{Y}_H^*$ and $\hat{Y}_F^*$ have equal and opposite effects on home welfare (as shown in equation (17)) so stabilisation of these outputs has no net welfare benefit to the home economy. It is therefore optimal for the home country to adopt money targeting. As in Case 2, money targeting and price targeting are equivalent because $\hat{P}_H^V = \hat{Y}_H + \hat{P} + \hat{C} = 2\hat{M}$.

The underlying explanation for these results is the following. When foreign producers follow LCP, home country consumers face prices which are fixed in the home currency and are therefore insulated from changes in the nominal exchange rate. There is therefore no expenditure switching effect for home consumption goods. Exchange rate volatility is thus unimportant for home consumption goods. There is, however, an expenditure switching effect for foreign consumption goods, but volatility in the output of foreign consumption goods has no net impact on home welfare, so exchange rate volatility is irrelevant for the home economy.[20]

## 4.4 Case 4: Home Producers Follow LCP, Foreign Producers Follow PCP

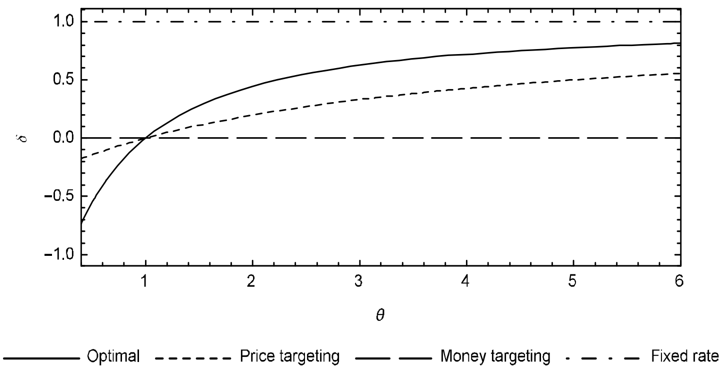
Case 2 and Case 3 both show a complete contrast to the results emphasised in Case 1. In both Case 2 and Case 3 a fixed exchange rate is the lowest ranked regime in terms of welfare. In both cases the expenditure switching effect, and thus exchange rate volatility, is largely (or completely) irrelevant for home country monetary policy. A policy of money targeting, or equivalently price targeting, is optimal, regardless of the value of the international trade

[20] There is a clear parallel between this result and a result obtained by Devereux *et al* (2007). Devereux *et al* analyse a model of a reference currency and find that the country with the reference currency is indifferent to exchange rate volatility while the non-reference country places a high welfare weight on exchange rate volatility. As with most of the LCP literature, Devereux *et al* focus on the implications of productivity shocks. Furthermore, unlike this paper, they do not compare monetary policy regimes. Instead they focus on a Nash equilibrium in the choice of monetary rules.

Table 5: Policy feedback parameter, welfare and exchange rate volatility in Case 4

| | Fixed rate | Money targeting | Price targeting | Optimal policy |
|---|---|---|---|---|
| $\delta$ | 1 | 0 | $\frac{\theta-1}{\theta+3}$ | $\frac{\theta^2+\theta-2}{(\theta+1)^2}$ |
| $\tilde{\Omega}$ | $-\sigma^2$ | $-\frac{(3+\theta^2)}{8}\sigma^2$ | $-\frac{2(\theta+1)^2}{(\theta+3)^2}\sigma^2$ | $-\left(\frac{7\theta^2+10\theta-1}{8(\theta+1)^2}\right)\sigma^2$ |
| $E\left[\hat{S}^2\right]$ | 0 | $\sigma^2$ | $\left(\frac{4}{\theta+3}\right)^2\sigma^2$ | $\left(\frac{\theta+3}{(\theta+1)^2}\right)^2\sigma^2$ |

Figure 7: $\delta$ in Case 4




elasticity, $\theta$. Clearly, the crucial feature of both cases is that foreign producers are following LCP. This is sufficient to insulate the home country from the exchange rate volatility caused by foreign money shocks and its welfare reducing effects.

Now consider Case 4, where home producers follow LCP and foreign producers follow PCP. In this case it is the foreign currency which can be regarded as the reference currency (such as the US dollar) while the home currency is a non-reference currency. The results for this case are given in Table 5 and illustrated in Figures 7, 8 and 9. These results show, in contrast to Cases 2 and 3, that exchange rate volatility is now very important for home welfare and home monetary policy. The assumption of PCP in the foreign country is clearly sufficient to expose the home country to the effects of foreign money shocks.

To understand these points in more detail first consider a comparison between money targeting and a fixed nominal exchange rate. As before, money targeting implies $\delta = 0$ and a fixed rate requires $\delta = 1$. Table 5 and Figure 8 show that, as in Case 1, money targeting yields higher welfare when $\theta$ is relatively low, while a fixed rate yields higher welfare for larger values of $\theta$. The output equations in Table 1 and the welfare expression (16) show that the underlying explanation for this results is the same as that given in Case 1. The

Figure 8: Welfare in Case 4

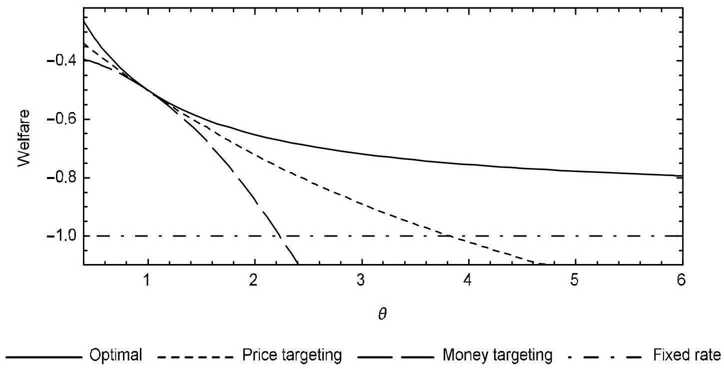
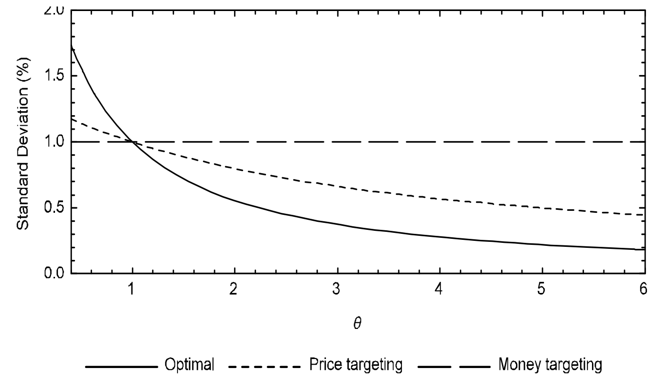



Figure 9: Exchange rate variability in Case 4




home monetary authority, in attempting to stabilise $\hat{Y}_H$ and $\hat{Y}_F$, faces a trade-off between stabilising $(\hat{M}+\hat{M}^*)$ and $(\hat{M}-\hat{M}^*)$. Money targeting yields a lower volatility of $(\hat{M}+\hat{M}^*)$ at the expense of higher volatility of $(\hat{M}-\hat{M}^*)$. This yields lower volatility of $\hat{Y}_H$ and $\hat{Y}_F$ (compared to a fixed exchange rate) when $\theta$ is relatively low. A fixed exchange rate completely stabilises $(\hat{M}-\hat{M}^*)$ at the expense of higher volatility of $(\hat{M}+\hat{M}^*)$. This yields lower volatility of $\hat{Y}_H$ and $\hat{Y}_F$ (compared to money targeting) when $\theta$ is relatively high.

As in Case 1, price targeting offers a compromise between the fixed rate and money targeting regimes (when $\theta > 1$) in the sense that $\delta$ lies between zero and unity. Price targeting therefore implies more exchange rate volatility than a fixed rate, but less exchange rate volatility than money targeting (for $\theta > 1$). Notice, however, that, unlike in Case 1, price targeting is not welfare superior to a fixed rate for all values of $\theta$. In fact, for values of $\theta$ greater than approximately 3.8 a fixed rate yields higher welfare than price targeting.[21] This is an important difference between Case 4 and Case 1 (where price targeting is always welfare superior to a fixed rate).

To understand this contrast between the performance of price targeting in Case 1 and

[21] Notice again that when $\theta < 1$ optimal policy implies higher exchange rate volatility than the other regimes. As previously explained, when $\theta < 1$ the welfare impact of exchange rate volatility is reversed.

Case 4 it is necessary to consider the impact of monetary policy on the volatility of $\hat{Y}_H^*$ and $\hat{Y}_F^*$ and the impact of these volatilities on home welfare. $\hat{Y}_H^*$ and $\hat{Y}_F^*$ are exogenous in Case 4 and thus have no implications for the comparison between policy regimes in that case. But in Case 1 home monetary policy *can* affect $\hat{Y}_H^*$ and $\hat{Y}_F^*$, so the difference between the performance of price targeting in Cases 1 and 4 must be related to these variables.

Notice from the welfare expression (16) that the variances of $\hat{Y}_H^*$ and $\hat{Y}_F^*$ have equal and opposite effects on home welfare. The variance of $\hat{Y}_H^*$ has a negative welfare impact, while the variance of $\hat{Y}_F^*$ has a positive welfare impact. Home welfare is thus decreasing in $E[\hat{Y}_H^{*2}]-E[\hat{Y}_F^{*2}]$. This difference in Case 4 is clearly zero. But the expressions for $\hat{Y}_H^*$ and $\hat{Y}_F^*$ in Table 1 for Case 1 show that $E[\hat{Y}_H^{*2}]-E[\hat{Y}_F^{*2}] = \theta E[(\hat{M}+\hat{M}^*)(\hat{M}-\hat{M}^*)] = \theta E[\hat{M}^2-\hat{M}^{*2}]$. In Case 1, therefore, this term contributes an extra negative impact of monetary activism which does not arise in Case 4. In other words, the optimal $\delta$ in Case 4 is greater than the optimal $\delta$ in Case 1 (when $\theta > 1$). Optimal policy in Case 4 therefore yields lower exchange rate volatility than in Case 1. Thus, in Case 4, for large values of $\theta$ a fixed exchange rate is closer to optimal policy than price targeting.

# 5 Conclusions

This paper analyses the implications of LCP in a two-country model where monetary shocks arise in the foreign country and the policy question is the choice of appropriate monetary regime for the home country. In the presence of foreign monetary shocks, the expenditure switching role of the exchange rate can have a potentially welfare reducing effect because it transmits the effects of foreign shocks to the home economy. LCP has obvious implications for the expenditure switching role of the exchange rate and this paper shows how LCP affects the welfare comparison between policy regimes in the face of foreign monetary shocks.

The paper considers four possible combinations of PCP and LCP. In the case where there is complete and symmetric LCP we find that the expenditure switching effect is absent and exchange rate movements play no part in transmitting foreign monetary shocks to the home country. This completely removes any incentive for the home country to stabilise the exchange rate. In this case, floating rate regimes are shown to be welfare superior to a fixed exchange rate. The conclusions are different, however, if LCP is *asymmetric*. In the case where home country producers adopt PCP while foreign producers adopt LCP, we find that the case for exchange rate *flexibility* is strengthened relative to the symmetric PCP case. But in the opposite case, where home producers follow LCP and foreign producers follow PCP, the case for exchange rate *stabilisation* is strengthened. In fact, in this second asymmetric case, a fixed rate can out-perform price targeting in welfare terms.

The second asymmetric case corresponds to a world where the foreign currency is an international reference currency (e.g. the US dollar). So the policy problem can be interpreted as the regime choice faced by countries (other than the USA) in a world where trade is priced in US dollars and where US monetary shocks cause fluctuations in the value of the dollar. The conclusion is that such countries can benefit by stabilising (or even fixing) the value of their currency against the dollar. This indeed corresponds to the monetary policy actually adopted by a wide range of emerging market countries.

The first asymmetric case corresponds to a world where the home currency is a reference currency, while monetary shocks are occurring in a non-reference currency. The conclusion, in this case, is that exchange rate flexibility is a useful way for the home country to insulate itself from foreign monetary shocks.

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# Appendix

## A: Portfolio Allocation, Asset Prices and Risk Sharing

There are four first-order conditions for the choice of asset holdings. After some rearrangement they imply the following four equations

$$E\left[C^{-1}y\right] = E\left[C^{-1}\right]q_H, \quad E\left[C^{-1}y^*\right] = E\left[C^{-1}\right]q_F \tag{A1}$$

$$E\left[C^{*-1}y\right] = E\left[C^{*-1}\right]q_H, \quad E\left[C^{*-1}y^*\right] = E\left[C^{*-1}\right]q_F \tag{A2}$$

Using the solution procedure outlined in Obstfeld and Rogoff (1996, pp. 302-3) it is possible to show that consumption levels in the two countries are given by

$$C = \frac{q_H\left[y + y^*\right]}{q_H + q_F}Q, \quad C^* = \frac{q_F\left[y + y^*\right]}{q_H + q_F}$$

and the two asset prices are given by

$$q_H = \frac{E\left[\frac{y}{y+y^*}\right]}{E\left[\frac{1}{y+y^*}\right]}, \quad q_F = \frac{E\left[\frac{y^*}{y+y^*}\right]}{E\left[\frac{1}{y+y^*}\right]} \tag{A3}$$

which implies

$$\frac{C}{C^*} = \frac{q_H}{q_F}Q = \frac{E\left[\frac{y}{y+y^*}\right]}{E\left[\frac{y^*}{y+y^*}\right]}Q \tag{A4}$$

which is equation (11) in the main text.

## B: Model solution

The equations of the model are summarised in Table 6. The equations in their exact form are shown in the first column and the second-order approximations are shown in the second column. The second-order terms from the approximate form of the equations are summarised in Table 7. Note that the first-order approximation of the model can be obtained from the equations in the second column of Table 6 by setting all the second-order terms equal to zero. Note also that, to a first-order approximation, all expected values are zero. The set of equations varies depending on the configuration of LCP and PCP in the two countries. In Case 1, where both home and foreign producers follow PCP, the relevant set of equations is (B1) to (B16) with second-order terms given by (B19) to (B26) in Table 7. In Case 2, where both home and foreign producers follow LCP, the relevant set of equations is (B1) to (B14) and (B17) and (B18) with second order terms (B19) to (B24) and (B27) and (B28). In Case 3, where home producers follow PCP and foreign producers

Table A1: Equations of the model

| Exact Equation | 2nd Order Approximation | |
|---|---|---|
| $P=\left[\frac{1}{2}P_H^{1-\theta}+\frac{1}{2}P_F^{1-\theta}\right]^{\frac{1}{1-\theta}}$ | $\hat{P}=\frac{1}{2}\hat{P}_H+\frac{1}{2}\hat{P}_F+\lambda_P$ | (B1) |
| $P^*=\left[\frac{1}{2}P_H^{*1-\theta}+\frac{1}{2}P_F^{*1-\theta}\right]^{\frac{1}{1-\theta}}$ | $\hat{P}^*=\frac{1}{2}\hat{P}_H^*+\frac{1}{2}\hat{P}_F^*+\lambda_{P^*}$ | (B2) |
| $Y_H=\frac{1}{2}C\left(\frac{P_H}{P}\right)^{-\theta}$ | $\hat{Y}_H=\hat{C}-\theta\left(\hat{P}_H-\hat{P}\right)$ | (B3) |
| $Y_F=\frac{1}{2}C\left(\frac{P_F}{P}\right)^{-\theta}$ | $\hat{Y}_F=\hat{C}-\theta\left(\hat{P}_F-\hat{P}\right)$ | (B4) |
| $Y_H^*=\frac{1}{2}C^*\left(\frac{P_H^*}{P^*}\right)^{-\theta}$ | $\hat{Y}_H^*=\hat{C}^*-\theta\left(\hat{P}_H^*-\hat{P}^*\right)$ | (B5) |
| $Y_F^*=\frac{1}{2}C^*\left(\frac{P_F^*}{P^*}\right)^{-\theta}$ | $\hat{Y}_F^*=\hat{C}^*-\theta\left(\hat{P}_F^*-\hat{P}^*\right)$ | (B6) |
| $y=(Y_HP_H/S+Y_H^*P_H^*)/P^*$ | $\hat{y}=\frac{1}{2}(\hat{Y}_H+\hat{P}_H-\hat{S})+\frac{1}{2}(\hat{Y}_H^*+\hat{P}_H^*)-\hat{P}^*+\lambda_y$ | (B7) |
| $y^*=(Y_FP_F/S+Y_F^*P_F^*/)/P^*$ | $\hat{y}^*=\frac{1}{2}(\hat{Y}_F+\hat{P}_F-\hat{S})+\frac{1}{2}(\hat{Y}_F^*+\hat{P}_F^*)-\hat{P}^*+\lambda_{y^*}$ | (B8) |
| $\frac{C}{C^*}=\frac{E\left[\frac{y}{y+y^*}\right]}{E\left[\frac{y^*}{y+y^*}\right]}\frac{SP^*}{P}$ | $\hat{C}-\hat{C}^*=E\left[\hat{y}\right]-E[\hat{y}^*]+\hat{S}+\hat{P}^*-\hat{P}$ | (B9) |
| $M/P=\chi C$ | $\hat{M}-\hat{P}=\hat{C}$ | (B10) |
| $M^*/P^*=\chi C^*$ | $\hat{M}^*-\hat{P}^*=\hat{C}^*$ | (B11) |
| $M=\bar{M}\left(M^*/\bar{M}^*\right)^{\delta}$ | $\hat{M}=\delta\hat{M}^*$ | (B12) |
| $P_H=\frac{\phi}{\phi-1}\frac{KE\left[Y_H^2\right]}{E[Y_H/(PC)]}$ | $\hat{P}_H=E[\hat{Y}_H+\hat{P}+\hat{C}]+\lambda_{P_H}+\xi_{P_H}$ | (B13) |
| $P_F^*=\frac{\phi}{\phi-1}\frac{KE\left[Y_F^{*2}\right]}{E\left[Y_F^*/(P^*C^*)\right]}$ | $\hat{P}_F^*=E[\hat{Y}_F^*+\hat{P}^*+\hat{C}^*]+\lambda_{P_F^*}+\xi_{P_F^*}$ | (B14) |
| $P_H^*=\frac{\phi}{\phi-1}\frac{KE\left[Y_H^{*2}\right]}{E\left[Y_H^*/(PC)\right]S}$ | $\hat{P}_H^*=E[\hat{Y}_H^*+\hat{P}+\hat{C}]-\hat{S}+\lambda_{P_H^*}+\xi_{P_H^*}$ | (B15) |
| $P_F=\frac{\phi}{\phi-1}\frac{KE\left[Y_F^2\right]S}{E[Y_F/(P^*C^*)]}$ | $\hat{P}_F=E[\hat{Y}_F+\hat{P}^*+\hat{C}^*]+\hat{S}+\lambda_{P_F}+\xi_{P_F}$ | (B16) |
| $P_H^*=\frac{\phi}{\phi-1}\frac{KE\left[Y_H^{*2}\right]}{E\left[SY_H^*/(PC)\right]}$ | $\hat{P}_H^*=E[\hat{Y}_H^*+\hat{P}+\hat{C}-\hat{S}]+\lambda_{P_H^*}+\xi_{P_H^*}$ | (B17) |
| $P_F=\frac{\phi}{\phi-1}\frac{KE\left[Y_F^2\right]}{E[Y_F/(SP^*C^*)]}$ | $\hat{P}_F=E[\hat{Y}_F+\hat{P}^*+\hat{C}^*+\hat{S}]+\lambda_{P_F}+\xi_{P_F}$ | (B18) |

Table A2: Second-order terms

| | | |
|---|---|---|
| $\lambda_P = \frac{1}{8}(1-\theta)(\hat{P}_H - \hat{P}_F)^2$ | | (B19) |
| $\lambda_{P^*} = \frac{1}{8}(1-\theta)(\hat{P}_H^* - \hat{P}_F^*)^2$ | | (B20) |
| $\lambda_y = \frac{1}{2}(\hat{Y}_H + \hat{P}_H - \hat{S} - \hat{Y}_H^* - \hat{P}_H^*)^2$ | | (B21) |
| $\lambda_{y^*} = \frac{1}{2}(\hat{Y}_F + \hat{P}_F - \hat{S} - \hat{Y}_F^* - \hat{P}_F^*)^2$ | | (B22) |
| $\lambda_{P_H} = 2E[\hat{Y}_H^2]$, | $\xi_{P_H} = -\frac{1}{2}E[(\hat{Y}_H - \hat{P} - \hat{C})^2]$ | (B23) |
| $\lambda_{P_F^*} = 2E[\hat{Y}_F^{*2}]$, | $\xi_{P_F^*} = -\frac{1}{2}E[(\hat{Y}_F^* - \hat{P}^* - \hat{C}^*)^2]$ | (B24) |
| | | |
| $\lambda_{P_H^*} = 2E[\hat{Y}_H^{*2}]$, | $\xi_{P_H^*} = -\frac{1}{2}E[(\hat{Y}_H^* - \hat{P} - \hat{C})^2]$ | (B25) |
| $\lambda_{P_F} = 2E[\hat{Y}_F^2]$, | $\xi_{P_F} = -\frac{1}{2}E[(\hat{Y}_F - \hat{P}^* - \hat{C}^*)^2]$ | (B26) |
| | | |
| $\lambda_{P_H^*} = 2E[\hat{Y}_H^{*2}]$, | $\xi_{P_H^*} = -\frac{1}{2}E[(\hat{Y}_H^* + \hat{S} - \hat{P} - \hat{C})^2]$ | (B27) |
| $\lambda_{P_F} = 2E[\hat{Y}_F^2]$, | $\xi_{P_F} = -\frac{1}{2}E[(\hat{Y}_F - \hat{S} - \hat{P}^* - \hat{C}^*)^2]$ | (B28) |

follow LCP, the relevant set of equations is (B1) to (B15) and (B18) with second order terms (B19) to (B25) and (B28). And in Case 4, where home producers follow LCP and foreign producers follow PCP, the relevant set of equations is (B1) to (B14) and (B16) and (B17) with second order terms (B19) to (B24) and (B26) and (B27). In each of the four cases the set of equations solves for the equilibrium values of vector $V$ where

$$V = \left[\begin{array}{cccccccccccccccc} \hat{P} & \hat{P}^* & \hat{Y}_H & \hat{Y}_F & \hat{Y}_H^* & \hat{Y}_F^* & \hat{y} & \hat{y}^* & \hat{S} & \hat{C} & \hat{C}^* & \hat{M} & \hat{P}_H & \hat{P}_F & \hat{P}_H^* & \hat{P}_F^* \end{array}\right]$$

To solve for welfare it is necessary to obtain a second-order accurate expression for $E[\hat{C}]$. It is useful to do this in two stages. In the first stage it is possible to solve for $E[\hat{C}]$ in terms of the second-order terms $\lambda_P$, $\lambda_{P^*}$ etc. to yield the following expression

$$\begin{aligned} E[\hat{C}] \quad = \quad & \frac{1}{2}E\left[\frac{1-5\theta}{8\theta}\lambda_{P_H} + \frac{1-\theta}{8\theta}\lambda_{P_H^*} - \frac{1+3\theta}{8\theta}\lambda_{P_F} - \frac{1-\theta}{8\theta}\lambda_{P_F^*}\right. \\ & +\frac{1-5\theta}{8\theta}\xi_{P_H} + \frac{1-\theta}{8\theta}\xi_{P_H^*} - \frac{1+3\theta}{8\theta}\xi_{P_F} - \frac{1-\theta}{8\theta}\xi_{P_F^*} \\ & \left.-(1+\theta)\lambda_P + \frac{1+\theta}{4\theta}\lambda_y - \frac{1+\theta}{4\theta}\lambda_{y^*}\right] \end{aligned}$$

This expression is identical for all permutations of LCP and PCP across the two countries.

In the second stage it is necessary to substitute for the second-order terms using the expressions in Table 7. The resulting expression for $E[\hat{C}]$ can be further simplified by evaluating second-order terms using first-order accurate expressions for realised values. As previously noted, the first-order approximation for the model is obtained from the first-order parts of the equations listed in column 2 of Table 6. By this means, it is possible to show in Cases 1 and 4 that

$$E\left[\begin{array}{c}\frac{1-5\theta}{8\theta}\xi_{P_H}+\frac{1-\theta}{8\theta}\xi_{P_H^*}-\frac{1+3\theta}{8\theta}\xi_{P_F}-\frac{1-\theta}{8\theta}\xi_{P_F^*}\\ -(1+\theta)\lambda_P+\frac{1+\theta}{4\theta}\lambda_y-\frac{1+\theta}{4\theta}\lambda_{y^*}\end{array}\right]=\frac{1}{8}(\theta-1)\theta E[\hat{S}^2] \tag{B29}$$

and thus

$$\begin{aligned} E[\hat{C}] &= \frac{1}{8}E\left\{-\frac{(5\theta-1)}{\theta}\hat{Y}_H^2-\frac{(\theta-1)}{\theta}\hat{Y}_H^{*2}\right. \\ &\qquad \left.-\frac{(3\theta+1)}{\theta}\hat{Y}_F^2+\frac{(\theta-1)}{\theta}\hat{Y}_F^{*2}+(\theta-1)\theta\hat{S}^2\right\}+O\left(\epsilon^3\right) \end{aligned} \tag{B30}$$

which is the welfare expression given in (16) in the main text. While in Cases 2 and 3 it can be shown that

$$E\left[\begin{array}{c}\frac{1-5\theta}{8\theta}\xi_{P_H}+\frac{1-\theta}{8\theta}\xi_{P_H^*}-\frac{1+3\theta}{8\theta}\xi_{P_F}-\frac{1-\theta}{8\theta}\xi_{P_F^*}\\ -(1+\theta)\lambda_P+\frac{1+\theta}{4\theta}\lambda_y-\frac{1+\theta}{4\theta}\lambda_{y^*}\end{array}\right]=0 \tag{B31}$$

and thus

$$\begin{aligned} E[\hat{C}] &= \frac{1}{8}E\left\{-\frac{(5\theta-1)}{\theta}\hat{Y}_H^2-\frac{(\theta-1)}{\theta}\hat{Y}_H^{*2}\right. \\ &\qquad \left.-\frac{(3\theta+1)}{\theta}\hat{Y}_F^2+\frac{(\theta-1)}{\theta}\hat{Y}_F^{*2}\right\}+O\left(\epsilon^3\right) \end{aligned} \tag{B32}$$

which is the welfare expression given in (17) in the main text.

A similar two-stage solution procedure can be used to show that $E[\hat{Y}_H]+E[\hat{Y}_H^2]=E[\hat{Y}_H^*]+E[\hat{Y}_H^{*2}]=0$. This confirms that $\tilde{\Omega}=E[\hat{C}]$.

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