Cost-Push Shocks and Monetary Policy in Open Economies

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Abstract

This paper analyses the implications of cost-push shocks for the optimal choice of monetary policy target in an two-country sticky-price model. In addition to cost-push shocks, each country is subject to labour-supply and money-demand shocks. It is shown that the fully optimal coordinated policy can be supported by independent national monetary authorities following a policy of flexible inflation targeting. A number of simple (but non-optimal) targeting rules are compared. Strict producer-price targeting is found to be the best simple rule when the variance of cost-push shocks is small. Strict consumer-price targeting is best for intermediate levels of the variance of cost-push shocks. And nominal-income targeting is best when the variance of cost-push shocks in high. In general, money-supply targeting and fixed nominal exchange rates are found to yield less welfare than these other regimes.

Keywords: monetary policy, inflation targeting, welfare.

JEL: E52, E58, F41

Zusammenfassung

Dieses Papier analysiert die Implikationen eines Cost-Push-Schocks für die optimale Wahl eines Zieles für die Geldpolitik in einem 2-Länder-Modell mit träger Preisanpassung. Neben einem Cost-Push-Schock erlebt jedes Land auch Arbeitsangebots- und Geldnachfrageschocks. Man kann sagen, dass die optimale koordinierte Politik durch unabhängige nationale Zentralbanken verwirklicht werden kann, die eine Strategie des flexiblen Inflation Targeting verfolgen. Eine Reihe einfacher (aber nicht optimaler) geldpolitischer Regeln wird verglichen. Eine Politik, bei der Ziele für die Produzentenpreise angestrebt werden, erweist sich als die beste einfache Regel, wenn die Varianz der Cost-Push-Schocks klein ist. Ziele für Konsumentenpreise sind am besten geeignet bei Cost-Push-Schocks mittlerer Stärke. Ziele für das Nominaleinkommen sind vorzuziehen, wenn die Varianz der Cost-Push-Schocks hoch ist. Im Allgemeinen sind in dem Modell Geldmengenziele oder eine Politik fester Wechselkurse wohlfahrts-ökonomisch diesen genannten Regimen unterlegen.

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1 Introduction

What is the optimal choice of monetary target for an open economy? Recent analyses of closed-economy general equilibrium models tend to suggest that strict targeting of consumer prices will maximise aggregate utility.[2] Such a policy minimises relative price distortions when some prices are sticky and unable to respond to shocks in the short run. But in an open economy there are more relative prices to consider. A particularly important additional concern is the relative price between home and foreign goods. Nevertheless, open economy contributions to the recent literature suggest that a welfare maximising monetary policy should focus on stabilising internal relative prices. This is achieved by strict targeting of producer prices.[3]

A number of cases where these basic results need to be modified have, however, been identified and analysed. The presence of non-optimal 'cost-push' shocks is one such case. Cost-push shocks can be caused by factors such as fluctuations in monopoly mark-ups which cause changes in prices but which do not imply any change in the socially optimal level of real output. In a closed economy context the presence of cost-push shocks implies that the optimal policy allows for some flexibility in consumer prices in order to allow some stabilisation of the output gap.[4] In an open economy context Clarida, Gali and Gertler (2001b) and Benigno and Benigno (2001b) show that the same result holds (but with consumer prices being replaced by producer prices).[5]

This paper analyses the implications of cost-push shocks for optimal monetary policy and the choice of monetary target in open economies. A two-country model is constructed where each country is subject to labour-supply, cost-push and money-

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[2]See Aoki (2001), Goodfriend and King (2001), King and Wolman (1999) and Woodford (2001).

[3]See Aoki (2001), Benigno and Benigno (2001a) and Clarida, Gali and Gertler (2001a).

[4]This is often referred to as 'flexible inflation targeting' following the terminology suggested by Svensson (1999, 2000).

[5]Further analysis of open economy models, where there is less than perfect pass-through from exchange rate changes to local currency prices, has shown that optimal monetary policy should involve some consideration of exchange rate volatility. (See Bacchetta and van Wincoop (2000), Corsetti and Pesenti (2001b), Devereux and Engel (1998, 2000), Engel (2001), Smets and Wouters (2001) and Sutherland (2001a).) In this case the monetary authority should allow some flexibility in producer prices in order to achieve some desired degree of volatility in the nominal exchange rate. Furthermore, Sutherland (2002) analyses the implications of the expenditure switching effect in a model where there is perfect pass-through. It is shown that, when the elasticity of substitution between home and foreign goods is greater than unity, exchange rate volatility can become an important factor in welfare even when there is full pass-through.

demand shocks.[6] The paper focuses on the choice of a world monetary regime and the implications for world aggregate welfare.[7] It is shown that (as in Benigno and Benigno (2001b)) the optimal coordinated policy can be supported by independent national monetary authorities following a policy of flexible inflation targeting. Such a policy implies that each national monetary authority minimises a loss function which depends on a weighted sum of producer-price volatility and output-gap volatility.

The analysis demonstrates an important feature of the recent literature, namely that the welfare maximising monetary strategy becomes more complex as more realistic aspects are added to the basic model. It is clear that the optimality of a simple strategy of strict consumer-price or producer-price targeting does not carry over to more general cases. In addition, even when the optimal monetary strategy can be summarised by a relatively simple loss function (as is the case in the model considered in this paper), it becomes doubtful that the fully optimal monetary policy can in practice be implemented. The fully optimal policy may involve responding to unobservable or unmeasurable variables or require a complex balance between different targets where the optimal weights to be placed on different targets are unmeasurable or uncertain. It is therefore useful to analyse the welfare performance of non-optimal but simple targeting rules.

After deriving the theoretically optimal policy regime, this paper considers a number of possible simple targeting rules. The rules considered include; money-supply targeting, strict targeting of producer prices, strict targeting of consumer prices, a fixed nominal exchange rate and nominal-income targeting. Nominal-income targeting is of particular interest when there are cost-push shocks. Nominal-income targeting implies that monetary policy stabilises both real output and prices to some extent. It is therefore a regime which shares some of the features of the fully optimal policy rule.[8]

It is found that money-supply targeting and fixed exchange rates are in general dominated by at least one of the other three regimes. Strict producer-price targeting is found to be the best simple rule when the variance of cost-push shocks is small. Strict consumer-price targeting is best for intermediate levels of the variance of cost-push shocks . And nominal-income targeting is best when the variance of cost-push shocks is high.

This paper proceeds as follows. Section 2 presents the model. Section 3 considers the general form of optimal monetary policy. Section 4 compares the welfare performance of a range of simple targeting rules. Section 5 concludes the paper.

[6]The model is in the 'new open economy macro' tradition (which originates with Obstfeld and Rogoff (1995)) in that it assumes monopolistic competition and sticky prices. The new open economy literature has been surveyed by Lane (2001).

[7]An obvious issue of interest (which is not tackled in this paper) is the welfare gain to coordinated monetary policy. In fact, in the model presented here there are no significant welfare gains to coordination. This contrasts with the models Benigno and Benigno (2001b) and Clarida, Gali and Gertler (2001b), where gains to coordination do arise.

[8]Nominal-income targeting has previously been analysed by Jensen (1999) and McCallum and Nelson (1999).

2 The Model

2.1 Market Structure

The world exists for a single period[9] and consists of two countries, which will be referred to as the home country and the foreign country. Each country is populated by agents who consume a basket consisting of all home and foreign produced goods. Each agent is a monopoly producer of a single differentiated product. There is a continuum of agents of unit mass in each country. Home agents are indexed $h \in [0, 1]$ and foreign agents are indexed $f \in [0, 1]$.

There are two categories of agent in each country. The first set of agents supply goods in a market where prices are set in advance of the realisation of shocks and the setting of monetary policy. Agents in this market are contracted to meet demand at the pre-fixed prices. Agents in this group will be referred to as 'fixed-price agents'. The second set of agents supply goods in a market where prices are set after shocks are realised and monetary policy is set. Agents in this group will be referred to as 'flexible-price agents'.[10] The proportion of fixed-price agents in the total population is denoted ψ so ψ is a measure of the degree of price stickiness in the economy. The total population of the home economy is indexed on the unit interval with fixed-price agents indexed $[0,\psi]$ and flexible-price agents indexed $(\psi, 1]$. Prices and quantities relating to fixed-price agents will be indicated with the subscript '1' while those relating to flexible-price agents will be indicated with the subscript '2'. The foreign economy has a similar structure.

This framework provides the minimal structure necessary to study the effects of price variability on welfare while allowing some degree of price stickiness. The fixed-price agents provide the nominal rigidity that is necessary to give monetary policy a role while the flexible-price agents provide the partial aggregate price flexibility that allows an analysis of the connection between price volatility and welfare.

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.

[9] The model can easily be recast as a multi-period structure but this adds no significant insights. A true dynamic model, with multi-period nominal contracts and asset stock dynamics would be considerably more complex and would require much more extensive use of numerical methods. Newly developed numerical techniques are available to solve such models and this is likely to be an interesting line of future research (see Kim and Kim (2000), Sims (2000), Schmitt-Grohé and Uribe (2001) and Sutherland (2001b)). However, the approach adopted in this paper yields useful insights which would not be available in a more complex model.

[10] This structure can be thought of as a static version of the Calvo (1983) staggered price setting framework. A fixed/flexible price structure similar to the one used here has previously been used in Aoki (2001) and Woodford (2001). The division of agents into fixed-price and flexible-price groups is taken to be a fixed institutional feature of the economy.

2.2 Preferences

All agents in the home economy have utility functions of the same form. The utility of agent z of type i is given by

$$U(z) = E\left[\log C(z) + \chi \log \frac{M(z)}{P} - \frac{K}{\mu} y_i^{\mu}(z)\right] \tag{1}$$

where $\mu \geq 1$, $i = 1$ for a fixed-price agent and $i = 2$ for a flexible-price agent, 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, $y_i(z)$ is the output of good z, E is the expectations operator, K is a log-normal stochastic labour-supply shock ($E[\log K] = 0$ and $Var[\log K] = \sigma_K^2$) and χ is a log-normal stochastic money-demand shock ($E[\log \chi] = 0$ and $Var[\log \chi] = \sigma_\chi^2$).

The consumption index C for home agents is defined as

$$C = \frac{C_H^{\nu} C_F^{1-\nu}}{\nu^{\nu}(1-\nu)^{1-\nu}} \tag{2}$$

where C_H and C_F are indices of home and foreign produced goods and $\nu = 1 - \gamma/2$ and $0 \leq \gamma \leq 1$. This formulation implies 'home bias' in consumption.[11] The parameter γ is effectively a measure of openness. $\gamma = 0$ implies a completely closed economy while $\gamma = 1$ implies a completely open economy.

The form of the utility function implies a unit elasticity of substitution between home and foreign goods. This ensures that there is no idiosyncratic income risk between the home country and the rest of the world. The structure of financial markets is therefore irrelevant.[12]

Utility from consumption of home and foreign goods is defined as follows

$$C_H = \frac{C_{H,1}^{\psi} C_{H,2}^{(1-\psi)}}{\psi^{\psi}(1-\psi)^{(1-\psi)}}, \quad C_F = \frac{C_{F,1}^{\psi} C_{F,2}^{(1-\psi)}}{\psi^{\psi}(1-\psi)^{(1-\psi)}} \tag{3}$$

where $C_{H,1}$and $C_{H,2}$ are indices of home fixed-price and flexible-price goods defined as follows

$$C_{H,1} = \left[\left(\frac{1}{\psi}\right)^{\frac{1}{\phi}} \int_0^{\psi} c_{H,1}(h)^{\frac{\phi-1}{\phi}} dh\right]^{\frac{\phi}{\phi-1}}, \quad C_{H,2} = \left[\left(\frac{1}{1-\psi}\right)^{\frac{1}{\phi}} \int_{\psi}^{1} c_{H,2}(h)^{\frac{\phi-1}{\phi}} dh\right]^{\frac{\phi}{\phi-1}}$$

[11] In this case 'home bias' implies home agents potentially give a higher weight to home goods than foreign goods and foreign agents give a higher weight to foreign goods than home goods.

[12] This assumption was introduced into a deterministic open economy model by Corsetti and Pesenti (2001a) and has proved to be a key assumption allowing a tractable solution to stochastic models of the type used in this paper.

and $C_{F,1}$and $C_{F,2}$ are indices of foreign fixed-price and flexible-price goods defined as follows

$$C_{F,1} = \left[\left(\frac{1}{\psi}\right)^{\frac{1}{\phi}} \int_0^{\psi} c_{F,1}(f)^{\frac{\phi-1}{\phi}} df\right]^{\frac{\phi}{\phi-1}}, \quad C_{F,2} = \left[\left(\frac{1}{1-\psi}\right)^{\frac{1}{\phi}} \int_{\psi}^{1} c_{F,2}(f)^{\frac{\phi-1}{\phi}} df\right]^{\frac{\phi}{\phi-1}}$$

where $c_{H,i}(h)$ is consumption of home good h produced by a home agent of type i and $c_{F,i}(f)$ is consumption of foreign good f produced by a foreign agent of type i.

The above functions imply a constant elasticity of substitution between different varieties of good of the same type and a unit elasticity of substitution between types of good.[13]

The budget constraint of agent z (where z is of type i) is given by

$$M(z) = M_0 + (1+\alpha) p_{H,i}(z)\, y_i(z) - PC(z) - T \tag{4}$$

where M_0 and $M(z)$ are initial and final money holdings, T is lump-sum government transfers, $p_{H,i}(z)$ is the price of home good z, α is a production subsidy and P is the aggregate consumer price index.

The government's budget constraint is

$$M - M_0 - \alpha P_H Y + T = 0 \tag{5}$$

where P_H is the aggregate price of home produced goods and Y is the aggregate output of the home economy.

2.3 Price indices

The aggregate consumer price index for home agents is

$$P = P_H^{\nu} P_F^{1-\nu} \tag{6}$$

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

The price indices of home and foreign goods are defined as

$$P_H = P_{H,1}^{\psi} P_{H,2}^{(1-\psi)}, \quad P_F = P_{F,1}^{\psi} P_{F,2}^{(1-\psi)} \tag{7}$$

where $P_{H,1}$ and $P_{H,2}$ are the price indices of home fixed-price and flexible-price goods defined as follows

$$P_{H,1} = \left[\frac{1}{\psi} \int_0^{\psi} p_{H,1}(h)^{1-\phi} dh\right]^{\frac{1}{1-\phi}}, \quad P_{H,2} = \left[\frac{1}{1-\psi} \int_{\psi}^{1} p_{H,2}(h)^{1-\phi} dh\right]^{\frac{1}{1-\phi}}$$

[13] The assumption that the elasticity of substitution between fixed-price and flexible-price goods differs from the elasticity of substitution between goods within each type has the slightly odd implication that the degree of price stickiness is in effect embedded in the structure of preferences. It would be possible to relax this assumption (and, for instance, have a common elasticity of ϕ between all goods) but the present assumption allows some useful simplifications of the algebra (because it ensures that all home agents have identical income and consumption levels regardless of which type they are).

and $P_{F,1}$ and $P_{F,2}$ are the price indices of foreign fixed-price and flexible-price goods defined as follows

$$P_{F,1} = \left[\frac{1}{\psi}\int_0^{\psi} p_{F,1}(f)^{1-\phi}\,df\right]^{\frac{1}{1-\phi}}, \quad P_{F,2} = \left[\frac{1}{1-\psi}\int_{\psi}^{1} p_{F,2}(f)^{1-\phi}\,df\right]^{\frac{1}{1-\phi}}$$

The law of one price is assumed to hold. This implies $p_{H,i}(j) = p^*_{H,i}(j)\,S$ and $p_{F,i}(j) = p^*_{F,i}(j)\,S$ for all i and j where an asterisk indicates a price measured in foreign currency and S is the exchange rate (defined as the domestic price of foreign currency). Note that purchasing power parity does not hold because home and foreign agents have different preferences over consumption (because of home bias).

The terms of trade are defined as $\tau = P_H/P_F = P_H/(SP^*_F)$.

2.4 Consumption Choices

Individual home demands for representative home fixed-price good, h_1, and flexible-price good, h_2, are

$$c_1(h_1) = \frac{1}{\psi}C_{H,1}\left(\frac{p_{H,1}(h_1)}{P_{H,1}}\right)^{-\phi}, \quad c_2(h_2) = \frac{1}{1-\psi}C_{H,2}\left(\frac{p_{H,2}(h_2)}{P_{H,2}}\right)^{-\phi} \tag{8}$$

where

$$C_{H,1} = \psi C_H\left(\frac{P_{H,1}}{P_H}\right)^{-1}, \quad C_{H,2} = (1-\psi)\,C_H\left(\frac{P_{H,2}}{P_H}\right)^{-1} \tag{9}$$

and where

$$C_H = \nu C\left(\frac{P_H}{P}\right)^{-1} \tag{10}$$

Individual home demands for representative foreign fixed-price good, f_1, and flexible-price good, f_2, are

$$c_1(f_1) = \frac{1}{\psi}C_{F,1}\left(\frac{p_{F,1}(f_1)}{P_{F,1}}\right)^{-\phi}, \quad c_2(f_2) = \frac{1}{1-\psi}C_{F,2}\left(\frac{p_{F,2}(f_2)}{P_{F,2}}\right)^{-\phi} \tag{11}$$

where

$$C_{F,1} = \psi C_F\left(\frac{P_{F,1}}{P_F}\right)^{-1}, \quad C_{F,2} = (1-\psi)\,C_F\left(\frac{P_{F,2}}{P_F}\right)^{-1} \tag{12}$$

and where

$$C_F = (1-\nu)C\left(\frac{P_F}{P}\right)^{-1} \tag{13}$$

Each country has a population of unit mass so the total home demands for goods are equivalent to the individual demands.

Symmetry between the home and foreign countries implies that the foreign demands for home and foreign goods are given by

$$C_H^* = (1-\nu)C^* \left(\frac{P_H^*}{P^*}\right)^{-1}, \quad C_F^* = \nu C^* \left(\frac{P_F^*}{P^*}\right)^{-1} \tag{14}$$

Individual and total foreign demands for individual goods have an identical structure to the home demands given above.

Using the above relationships it is simple to verify that fixed-price and flexible-price agents have the same income levels (and therefore choose the same consumption levels). It is also possible to verify that financial markets are irrelevant. To see this latter point note that current account balance implies

$$SP_H^* C_H^* = P_F C_F \tag{15}$$

which, when combined with the above expressions for C_H^* and C_F, implies

$$\left(\frac{C^*}{C}\right)^{-1} = \frac{SP^*}{P} \tag{16}$$

This equation shows that, when the current account is in balance, the ratio of marginal utilities across the two countries is equal to the ratio of aggregate prices (i.e. the real exchange rate). This implies that there can be no Pareto improving reallocation of consumption across countries. Financial markets are therefore redundant.

2.5 Optimal Price Setting

Individual agents are each monopoly producers of a single differentiated good. They therefore set prices as a mark-up over marginal costs. The mark-up is given by $\phi/(\phi-1)$. The mark-up is offset by a production subsidy, α, which is paid to all producers (financed out of lump-sum taxes). It is useful to define the net mark-up as follows $A \equiv \phi/\left[(\phi-1)(1+\alpha)\right]$.

Cost-push shocks are assumed to enter the model through shocks to the net mark-up such that A is log-normally distributed with $E[\log A] = 0$ and $Var[\log A] = \sigma_A^2$. The underlying source of these shocks may be assumed to be random changes in the production subsidy or the degree of monopoly power (i.e. ϕ). The important feature of these cost-push shocks is that they are non-optimal in the sense that they change private pricing and production incentives but they do not change the socially optimal level of production and work effort.

Flexible-price producers are able to set prices after shocks have been realised and monetary policy has been set. In equilibrium all flexible-price producers set the same price so $P_{H,2} = p_{H,2}(h_2)$ for all h_2. The first order condition for the choice of price is derived in the Appendix and implies the following

$$P_{H,2} = AKY_2^{\mu-1}PC \tag{17}$$

where Y_2 is the output of home flexible-price producers (expressed *per capita* of the population of home flexible-price producers), which is given by

$$Y_2 = \frac{1}{1-\psi}\left(C_{H,2} + C^*_{H,2}\right) = Y\left(\frac{P_{H,2}}{P_H}\right)^{-1} \tag{18}$$

where Y is the total output of the home economy, which is given by

$$Y = C_H + C^*_H = C\left(\frac{P_H}{P}\right)^{-1} \tag{19}$$

Fixed-price agents must set prices before shocks have been realised and monetary policy is set. The first order condition for fixed-price producers is derived in the Appendix and is given by the following

$$P_{H,1} = \frac{E\left[KY_1^{\mu}\right]}{E\left[Y_1/(APC)\right]} \tag{20}$$

where Y_1 is the output of home fixed-price producers (expressed *per capita* of the population of home fixed-price producers), which is given by

$$Y_1 = \frac{1}{\psi}\left(C_{H,1} + C^*_{H,1}\right) = Y\left(\frac{P_{H,1}}{P_H}\right)^{-1} \tag{21}$$

The important difference between the pricing condition for fixed-price producers when compared to the pricing condition for flexible-price producers is the presence of the expectations operator.

It is useful to define $V_1 \equiv KY_1^{\mu}$ and $V_2 \equiv Y_1/(APC)$ so $P_{H,1} = E\left[V_1\right]/E\left[V_2\right]$. All the variables of the model are log-normal so it is possible to write

$$\hat{P}_{H,1} = E\left[\hat{V}_1 - \hat{V}_2\right] + \lambda_{P_H} \tag{22}$$

where $\lambda_{P_H} = \left\{Var\left[\hat{V}_1\right] - Var\left[\hat{V}_2\right]\right\}/2$, $\hat{V}_1 = \hat{K} + \mu\hat{Y}_1$ and $\hat{V}_2 = \hat{Y}_1 - \hat{P} - \hat{C} - \hat{A}$ and where a hat indicates the log deviation of a variable from a non-stochastic steady state. Equation (22) shows that the prices of fixed-price agents will contain a form of risk premium which reflects the fact that prices are set in advance of shocks being realised. It will be shown below that, given the solution procedure adopted in this paper, this risk premium in fact plays no direct role in the analysis presented in this paper.[14]

[14]This risk premium has previously been noted and analysed in Rankin (1998) and plays a central role in the analyses of Obstfeld and Rogoff (1998, 2000, 2002), Devereux and Engel (1998, 2000), Corsetti and Pesenti (2001b) and Sutherland (2000, 2001a). The fact that it appears to play no role in this paper is simply a result of the focus on world aggregate welfare and the solution procedure adopted. It does not imply that the risk premium is quantitatively small.

2.6 Money Demand and Supply

The first order condition for the choice of money holdings is

$$\frac{M}{P} = \chi C \tag{23}$$

It is assumed that the monetary authority adjusts the money stock so as to achieve whatever target is being considered.

2.7 Home and Foreign Shocks

The foreign economy has a structure identical to the home economy. The foreign economy is subject to labour-supply, cost-push and money-demand shocks of the same form as the home economy. For simplicity it is assumed that the variances of the shocks are identical across the two countries, i.e.

$$\sigma_K^2 = \sigma_{K^*}^2, \quad \sigma_A^2 = \sigma_{A^*}^2, \quad \sigma_\chi^2 = \sigma_{\chi^*}^2 \tag{24}$$

In addition the cross-country correlation of shocks is assumed to be identical for all three types of shocks, i.e.

$$\rho_{KK^*} = \rho_{AA^*} = \rho_{\chi\chi^*} = \rho \tag{25}$$

where $-1 \leq \rho \leq 1$.

2.8 Welfare

One of the main advantages of the model just described is that it provides a very natural and tractable measure of welfare which can be derived from the aggregate utility of agents. The focus of this paper is the coordinated choice of monetary policy and its implications for world aggregate welfare. It is therefore necessary to consider an aggregation of utility across the world population. Following Obstfeld and Rogoff (1998, 2000) it is assumed that the utility of real balances is small enough to be neglected. It is therefore possible to measure world *ex ante* aggregate welfare using the following

$$\begin{aligned} \Omega \;=\; E\Bigg[&\psi\left(\log C - \frac{K}{\mu}Y_1^\mu\right) + (1-\psi)\left(\log C - \frac{K}{\mu}Y_2^\mu\right) \\ &+\psi\left(\log C^* - \frac{K^*}{\mu}Y_1^{*\mu}\right) + (1-\psi)\left(\log C^* - \frac{K^*}{\mu}Y_2^{*\mu}\right)\Bigg] \end{aligned} \tag{26}$$

The next section explains how this expression can be simplified and used to analyse welfare maximising monetary policy.

3 Welfare Maximising Monetary Policy

It is convenient to proceed by first deriving a second-order approximation of the welfare function around a non-stochastic steady state. Define $\bar{X}$ to be the steady state value of variable X. The non-stochastic steady state is one where the production subsidy has been chosen to eliminate the monopoly mark-up. It is simple to show that this equilibrium will imply $\bar{Y} = \bar{C} = 1$.

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

$$\begin{aligned}\Omega_D = E\Big\{&\hat{C} + \hat{C}^* - \psi\hat{Y}_1 - (1-\psi)\hat{Y}_2 - \psi\hat{Y}_1^* - (1-\psi)\hat{Y}_2^* \\ &- \frac{\psi\mu}{2}\left(\hat{Y}_1 + \frac{\hat{K}}{\mu}\right)^2 - \frac{(1-\psi)\mu}{2}\left(\hat{Y}_2 + \frac{\hat{K}}{\mu}\right)^2 \\ &- \frac{\psi\mu}{2}\left(\hat{Y}_1^* + \frac{\hat{K}^*}{\mu}\right)^2 - \frac{(1-\psi)\mu}{2}\left(\hat{Y}_2^* + \frac{\hat{K}^*}{\mu}\right)^2\Big\} + O\left(\|\xi\|^3\right) \qquad (27)\end{aligned}$$

where Ω_D is the deviation of the level of welfare from the non-stochastic steady state. The term $O\left(\|\xi\|^3\right)$ contains all terms of third order and higher in deviations from the non-stochastic steady state. (After some further rearrangement of (27) it turns out that the residual term, $O\left(\|\xi\|^3\right)$, is zero, so the final expression for welfare derived below is exact.)

Expression (27) can be greatly simplified by noting that equations (18), (19) and (21) and their foreign counterparts imply that

$$\hat{C} + \hat{C}^* - \psi\hat{Y}_1 - (1-\psi)\hat{Y}_2 - \psi\hat{Y}_1^* - (1-\psi)\hat{Y}_2^* = 0 \qquad (28)$$

Thus all the first-order terms in (27) can be cancelled and only second-order terms matter for determining welfare.[15]

A further simplification can be achieved by noting that equations (17) and (18) and their foreign counterparts imply that the output levels of home and foreign flexible-price producers are given by

$$\hat{Y}_2 = -\frac{\hat{K} + \hat{A}}{\mu}, \quad \hat{Y}_2^* = -\frac{\hat{K}^* + \hat{A}^*}{\mu} \qquad (29)$$

Thus the output of the flexible-price sector is exogenously determined and unaffected by monetary policy. Welfare is therefore given by

$$\Omega_D = -\frac{\psi\mu}{2}E\left\{\left(\hat{Y}_1 + \frac{\hat{K}}{\mu}\right)^2 + \left(\hat{Y}_1^* + \frac{\hat{K}^*}{\mu}\right)^2\right\} + tip + O\left(\|\xi\|^3\right) \qquad (30)$$

[15] That fact that all first-order terms can be deleted from the welfare measure implies that it is not necessary to consider the implications of the risk premia in the prices of fixed-price goods.

where *tip* indicates 'terms independent of policy' (which includes terms relating to the output of flexible-price agents). With some further rearrangement it is possible to write welfare as follows

$$\Omega_D = -\frac{\psi\mu}{2}\left\{Var\left[\hat{Y}_1 + \frac{\hat{K}}{\mu}\right] + Var\left[\hat{Y}_1^* + \frac{\hat{K}^*}{\mu}\right]\right\} + tip \tag{31}$$

Note that this final rearrangement allows the residual, $O\left(\|\xi\|^3\right)$, to be deleted, so (31) is an exact expression for welfare.[16] This equation shows that policy affects welfare only through the impact of policy on the variability of output levels of fixed-price agents.

In order to see what (31) implies for optimal policy it is necessary to consider the determinants of fixed-price output. Using (19), (21) and (23) it can be shown that home fixed-price output is given by

$$\hat{Y}_1 = \hat{M} - \hat{\chi} - \hat{P}_{H,1} \tag{32}$$

and foreign fixed-price output is given by

$$\hat{Y}_1^* = \hat{M}^* - \hat{\chi}^* - \hat{P}_{F,1}^* \tag{33}$$

In these expressions the terms in $\hat{P}_{H,1}$ and $\hat{P}_{F,1}^*$ are fixed *ex ante* so the variances of fixed-price outputs depend only on the money supplies and monetary shocks.

It is immediately apparent that welfare maximising monetary policy is given by

$$\hat{M} = \hat{\chi} - \frac{\hat{K}}{\mu}, \quad \hat{M}^* = \hat{\chi}^* - \frac{\hat{K}^*}{\mu} \tag{34}$$

The optimal monetary rules imply full accommodation of money-demand shocks. The optimal rules also imply a negative relationship between the money supply and labour-supply shocks. This is easily understood. Consider, for instance, a positive shock to K. This represents an increase in the marginal disutility of work effort which, in turn, must imply a reduction in the socially optimal level of work effort. Flexible-price agents can bring about this reduction in work effort by raising prices (as is implied by (17) and (29)). But fixed-price agents are locked into price contracts which cannot be adjusted in the light of shocks. The optimal monetary policy response in these circumstances is to reduce the money supply in a way which reproduces the socially optimal reduction in fixed-price output. The same logic applies to a negative shock to K (which implies an increase in the socially optimal level of work effort and an increase in the money supply).

Notice that optimal policy does not involve any response to cost-push shocks. Cost-push shocks (which in this model are assumed to arise from random fluctuations in the net mark-up) do not change the socially optimal level of work effort. There

[16] The Appendix gives a more detailed explanation of this point.

is therefore no need to use monetary policy to bring about changes in fixed-price output.

It is useful to consider the implications of optimal policy for producer prices. Using (7), (17) and (29) it is possible to show that home and foreign producer prices are given by

$$\hat{P}_H = \psi \hat{P}_{H,1} + (1-\psi)\left(\frac{\hat{A}+\hat{K}}{\mu} + \hat{M} - \hat{\chi}\right) \tag{35}$$

$$\hat{P}^*_F = \psi \hat{P}^*_{F,1} + (1-\psi)\left(\frac{\hat{A}^*+\hat{K}^*}{\mu} + \hat{M}^* - \hat{\chi}^*\right) \tag{36}$$

These expressions show that optimal policy completely eliminates any impact on producer prices of labour-supply and money-demand shocks but allows producer prices to vary in response to cost-push shocks.

Notice that optimal policy implies that fixed-price and flexible-price outputs respond differently to cost-push shocks. Fixed-price output is insulated against cost-push shocks while flexible-price output responds to cost-push shocks in exactly the same way as it responds to labour-supply shocks (see (29)). This highlights the fundamental differences between labour-supply shocks and cost-push shocks. Labour-supply shocks change both private and social incentives and therefore imply changes in the private and socially optimal levels of output. Cost-push shocks, on the other hand, change private incentives but have no impact on the socially optimal level of output. Welfare maximising monetary policy therefore ensures that fixed-price output responds only to socially optimal shocks. But flexible-price agents respond to the private incentives created by cost-push shocks and thus increase prices and reduce output in response to positive shocks to A.

It is clear from (35) and (36) that, in the presence of cost-push shocks, optimal policy does not imply completely stable producer prices. Thus strict targeting of producer price inflation in each country will not be consistent with optimal policy.

It is simple to show, however, that a form of flexible inflation targeting in each country does reproduce the optimal policy rule. To see this, first define the natural levels of output for the home and foreign countries to be the following

$$\hat{Y}_N = -\frac{\hat{K}}{\mu}, \quad \hat{Y}^*_N = -\frac{\hat{K}^*}{\mu} \tag{37}$$

These are the socially optimal levels of total output. Notice that $\hat{Y}_N$ and $\hat{Y}^*_N$ depend only on labour-supply shocks and are unaffected by cost-push shocks. Define the output gap for the home and foreign countries as follows

$$\hat{Y}_G = \hat{Y} - \hat{Y}_N = \hat{Y} + \frac{\hat{K}}{\mu}, \quad \hat{Y}^*_G = \hat{Y}^* - \hat{Y}^*_N = \hat{Y}^* + \frac{\hat{K}^*}{\mu} \tag{38}$$

It is now possible to define the following loss functions for the home and foreign monetary authorities

$$L = \hat{P}_H^2 + \frac{1-\psi}{\psi}\hat{Y}_G^2, \qquad L^* = \hat{P}_F^{*2} + \frac{1-\psi}{\psi}\hat{Y}_G^{*2} \tag{39}$$

It is simple to show that, if the home monetary authority minimises L and the foreign monetary authority minimises L^*, the optimal policy rules will be reproduced. A policy regime such as this could be described as a form of flexible inflation targeting because each monetary authority is stabilising a weighted sum of producer-price volatility and output-gap volatility.[17]

This result corresponds to the results of Benigno and Benigno (2001b), who show that, in the presence of cost-push shocks, the world coordinated monetary policy can be supported by a policy of flexible inflation targeting in each country.[18]

4 Simple Targeting Rules

It is apparent from the previous section that the optimal monetary strategy in this model economy is relatively easy to specify. A closed-form solution for the welfare function is derived and its implications for the optimal monetary rule are clear. It is even possible to see that the optimal monetary rule can be implemented by independent national monetary authorities minimising loss functions which are weighted sums of producer-price volatility and output-gap volatility. Nevertheless, despite these clear results, there are reasons to suppose that the practical implementation of such an optimal policy could be difficult. The optimal rule requires observations of the underlying shocks and the ability to distinguish between labour-supply and cost-push shocks. If policy is implemented in the form of flexible producer-price targeting then it is necessary to measure the output gap. This is not a directly observable variable. Even if these problems can be overcome it is not clear how minimising a loss function can be translated into the practical day to day business

[17] Notice that the weight on the output gap depends only on the degree of price rigidity and not on the variance of cost-push shocks. If there were no cost-push shocks then producer prices and the output gap would be perfectly correlated so there would be no difference between producer-price and output-gap targeting - both would produce the optimal policy. Notice also that these loss functions become inappropriate for extreme values of ψ. For $\psi = 0$ the weight on the output gap is infinite. But in this case there are no sticky prices so monetary policy is powerless and the optimal monetary rule is undefined. In the opposite extreme, when $\psi = 1$, the weight on the output gap is zero, but producer prices are completely rigid so it is no longer meaningful to consider policy in terms of producer-price targeting.

[18] In contrast to Benigno and Benigno (2001b) and Clarida, Gali and Gertler (2001b), there are no significant gains from coordination in this model. A non-unit elasticity of substitution between home and foreign goods (as in Benigno and Benigno) and a utility function which is non-logarithmic in consumption (as in Benigno and Benigno and Clarida, Gali and Gertler) imply cross-country spillover effects of monetary policy when there are cost-push shocks. It is these features which generate the gains from monetary policy coordination identified by these other authors.

Regime	**Targets**
1. Money	$\hat{M} = \hat{M}^* = 0$
2. Producer prices	$\hat{P}_H = \hat{P}_F^* = 0$
3. Consumer prices	$\hat{P} = \hat{P}^* = 0$
4. Nominal income	$\hat{P}_H^* + \hat{Y}^* = \hat{P}_H + \hat{Y} = 0$
5. Symmetric fixed exchange rate	$(\hat{P} + \hat{P}^*)/2 = \hat{S} = 0$
6. Exchange rate/money	$\hat{M}^* = \hat{S} = 0$
7. Exchange rate/producer prices	$\hat{P}_F^* = \hat{S} = 0$
8. Exchange rate/consumer prices	$\hat{P}^* = \hat{S} = 0$

Table 1: Targeting regimes

of setting monetary policy. For these reasons it is useful to consider and compare a range of non-optimal but simple targeting rules.

In the context of the current model there are a number of possible target variables, namely: the money supply, producer prices, consumer prices, nominal income and the nominal exchange rate. These target variables can be combined in different ways to characterise a number of possible regimes. The full list of regimes considered is given in Table 1.[19]

The first four regimes to be considered are symmetric regimes where home monetary policy is used to achieve a target for a home variable and foreign monetary policy is used to achieve a target for the corresponding foreign variable.

The last four regimes in Table 1 list a number of alternative fixed exchange rate regimes. Using (16) and (23) (and its foreign counterpart) it is simple to show that the nominal exchange rate is given by

$$\hat{S} = \left(\hat{M} - \hat{\chi}\right) - \left(\hat{M}^* - \hat{\chi}^*\right) \tag{40}$$

Thus any policy rule which implies $\hat{M} - \hat{M}^* = \hat{\chi} - \hat{\chi}^*$ yields a fixed nominal exchange rate. A fixed exchange rate therefore only ties down the difference between home and foreign money supplies. To complete the characterisation of monetary policy it is necessary also to specify a rule which determines the absolute level of M or M^*. Regime 5 is a symmetric fixed exchange rate regime where the absolute levels of M and M^* are tied down by a target for aggregate consumer prices across the two countries.[20] Regimes 6, 7 and 8 are all asymmetric fixed exchange rate regimes where the absolute level of M^* is tied down by a target for a foreign nominal variable (either the money supply, producer prices or consumer prices) while home monetary policy is used to target the nominal exchange rate.

[19] For the purposes of this exercise, targeting variable X is taken to mean that the monetary authority adopts a rule which ensures that *ex post* $\hat{X} = 0$.

[20] If the nominal exchange rate is fixed then the fact that P and P^* are in different currencies is irrelevant for forming a common consumer-price target. It can be shown that targeting world aggregate consumer prices is equivalent to targeting world aggregate producer prices.

Regime	**World Welfare**
1. Money	$-\frac{\psi\left(\sigma_K^2+\mu^2\sigma_\chi^2\right)}{\mu}$
2. Producer prices	$-\frac{\psi\sigma_A^2}{\mu}$
3. Consumer prices	$-\frac{\psi\left[(1-\rho)\gamma^2\sigma_K^2+\left[2B^2-(2B-\gamma)(1-\rho)\gamma\right]\sigma_A^2\right]}{2\mu B^2}$
4. Nominal income	$-\frac{\psi\sigma_K^2}{\mu}$
5. Symmetric exchange rate	$-\frac{\psi\left[(1-\rho)\sigma_K^2+(1+\rho)\sigma_A^2\right]}{2\mu}$
6. Exchange rate/money	$-\psi\left(\sigma_K^2+\mu^2\sigma_\chi^2\right)$
7. Exchange rate/producer prices	$-\frac{\psi\left[(1-\rho)\sigma_K^2+\sigma_A^2\right]}{\mu}$
8. Exchange rate/consumer prices	$-\frac{\psi\left[(1-\rho)[2-\gamma(2-\gamma)]\sigma_K^2+[2-(1-\rho)\gamma(2-\gamma)]\sigma_A^2\right]}{2\mu}$

Table 2: Welfare Levels

Note that nominal-income targeting (regime 4) implies $\hat{P}^* + \hat{C}^* = \hat{P} + \hat{C} = 0$. Nominal-income targeting is therefore supported by monetary rules of the form $\hat{M} = \hat{\chi}$ and $\hat{M}^* = \hat{\chi}^*$, which (from (40)) imply a fixed nominal exchange rate. Thus, within this model, nominal-income targeting is also a form of fixed exchange rate regime. Nominal-income targeting is interesting in the present context because it implies stabilising a combination of real output and producer prices. It therefore shares some of the characteristics of the fully optimal policy rule.

The derivation of the world welfare level implied by each targeting regime is given in the Appendix. The welfare levels are given in Table 2 (where $B \equiv 1 - \psi(1-\gamma)$).

Using the welfare levels given in Table 2 it is possible to state and prove a series of propositions which establish the welfare ranking of the different regimes. Proposition 1 compares the welfare yielded by each of the asymmetric fixed exchange rate regimes with the corresponding symmetric regime.

Proposition 1 *(a) The level of welfare yielded by symmetric targeting of money supplies (regime 1) is greater than or equal to the level of welfare yielded by asymmetric targeting of the exchange rate and the foreign money supply (regime 6); (b) The level of welfare yielded by symmetric targeting of producer prices (regime 2) is greater than or equal to the level of welfare yielded by asymmetric targeting of the exchange rate and foreign producer prices (regime 7); (c) The level of welfare yielded by symmetric targeting of consumer prices (regime 3) is greater than or equal to the level of welfare yielded by asymmetric targeting of the exchange rate and foreign consumer prices (regime 8).*

Proof. Proofs follow from comparison of the expressions given in Table 2 ■

This proposition demonstrates that each symmetric regime yields equal or higher welfare than the corresponding asymmetric regime for all parameter values.[21] It is

[21] This result is perhaps not surprising in a model where the two countries have indentical structures and parameter values and are subject to the same sources of shocks.

therefore possible to disregard the asymmetric regimes in further comparison of the other regimes.

Proposition 2 compares the welfare yielded by the money targeting and nominal-income targeting regimes.

Proposition 2 *The level of welfare yielded by nominal-income targeting (regime 4) is greater than or equal to the level of welfare yielded by symmetric money targeting (regime 1).*

Proof. The proof follows from comparison of the expressions given in Table 2 ■

Nominal-income targeting yields equal or higher welfare than money-supply targeting because of money-demand shocks. Money-supply targeting is identical to nominal-income targeting except that money-supply targeting does not accommodate money-demand shocks. Money-supply targeting therefore allows money-demand shocks to create volatility in real output while nominal-income targeting completely offsets such shocks. It is therefore possible to disregard money-supply targeting in the further comparison of the other regimes.

Proposition 3 compares the symmetric fixed rate regime with producer-price targeting and nominal-income targeting.

Proposition 3 *(a) The level of welfare yielded by nominal-income targeting is greater than or equal to the level of welfare yielded by a symmetric fixed exchange rate when* $\sigma_A^2 \geq \sigma_K^2$. *(b) The level of welfare yielded by producer-price targeting is greater than or equal to the level of welfare yielded by a symmetric fixed exchange rate when* $\sigma_A^2 \leq \sigma_K^2$.

Proof. Proofs follow from comparison of the expressions given in Table 2 ■

This proposition establishes that the symmetric fixed exchange rate regime (with world consumer-price targeting) is equivalent to or dominated by at least one of the other targeting regimes for all parameter values. It is therefore possible to disregard this regime in the further comparison of the other regimes.

There are now just three remaining regimes to consider: symmetric producer-price targeting (regime 2), symmetric consumer-price targeting (regime 3) and symmetric nominal-income targeting (regime 4). The relative ranking of these three regimes depends on the relative volatility of cost-push and labour-supply shocks. It is therefore useful to analyse the relative welfare performance in terms of σ_A^2/σ_K^2.

In what follows X_1 is used to denote the value of σ_A^2/σ_K^2 at which producer-price targeting yields the same level of welfare as consumer-price targeting and X_2 is used to denote the value of σ_A^2/σ_K^2 at which consumer-price targeting yields the same level of welfare as nominal-income targeting. Using the welfare expressions in Table 2 it follows that

$$X_1 = \frac{\gamma}{2B - \gamma} \tag{41}$$

$$X_2 = \frac{2B^2 - (1-\rho)\gamma^2}{2B^2 - (2B-\gamma)(1-\rho)\gamma} \tag{42}$$

The following proposition can now be proved.

Proposition 4 *When $-1 \leq \rho < 1$ and $\gamma > 0$: (a) $X_1 < 1 < X_2$. (b) When $\sigma_A^2/\sigma_K^2 < X_1$ producer-price targeting yields higher welfare than consumer-price targeting and nominal-income targeting. (c) When $X_1 < \sigma_A^2/\sigma_K^2 < X_2$ consumer-price targeting yields higher welfare than producer-price targeting and nominal-income targeting. (d) When $\sigma_A^2/\sigma_K^2 > X_2$ nominal-income targeting yields higher welfare than producer-price targeting and consumer-price targeting.*

Proof. Proofs follow from comparison of the expressions given in Table 2 ■

This proposition shows that, when cost-push shocks are relatively unimportant, producer-price targeting is a reasonably good approximation for fully optimal policy. But when cost-push shocks are very important, nominal-income targeting becomes a good approximation for fully optimal policy. And for an intermediate range of values for σ_A^2/σ_K^2, consumer-price targeting is the best approximation for fully optimal policy.

It is clear from (34), (35) and (36) that fully optimal policy involves completely stabilising producer prices when there are no cost-push shocks. It therefore follows that producer-price targeting is a good approximation for fully optimal policy when the variance of cost-push shocks is low. It is also clear from the discussion in the previous section that, in the presence of cost-push shocks, fully optimal policy involves stabilising a weighted sum of output-gap and producer-price volatility. Nominal-income targeting implies stabilising both output and prices so it follows that nominal-income targeting is a good approximation for fully optimal policy when the variance of cost-push shocks is very high. In the intermediate region, where the variance of cost-push shocks is relatively high, but not yet high enough to make nominal-income targeting best, consumer-price targeting offers a nominal anchor which allows some flexibility in producer prices. This flexibility is sufficient to allow consumer-price targeting to yield higher welfare than producer-price targeting for intermediate values of σ_A^2/σ_K^2.

Figures 1, 2 and 3 illustrate the effects of some of the model's parameters on X_1 and X_2 (the threshold values of σ_A^2/σ_K^2 at which the ranking of regimes changes). The benchmark parameter values are $\mu = 2.0$, $\gamma = \psi = 0.5$ and $\rho = 0.0$. Figure 1 shows that the degree of price stickiness, ψ, has relatively little impact on the values of X_1 and X_2. The main effect is that the range of values of σ_A^2/σ_K^2 for which consumer-price targeting is best shrinks to zero for very high values of ψ.

Figure 2 shows the effects of varying the degree of openness as measured by γ. The degree of openness has its main effect on X_1. For very closed economies X_1 is very low so consumer-price targeting is better than producer-price targeting for quite low values of σ_A^2/σ_K^2. But for very open economies X_1 is high so σ_A^2/σ_K^2 needs to be quite large before consumer-price targeting dominates producer-price targeting.

Figure 3 shows the effects of varying the degree of cross-country correlation of shocks (as measured by ρ). Varying ρ only affects X_2 but the effect is quite substantial. For strong negative cross-country correlation X_2 is very high. When $\rho = -1$ X_2 is approximately equal to five, so cost-push shocks need to be more than five times more volatile than labour-supply shocks before nominal-income targeting dominates consumer-price targeting. But for $\rho = 1$ X_2 is approximately equal to unity, so nominal-income targeting is the best simple rule for much lower values of σ_A^2/σ_K^2.

5 Conclusion

This paper has shown that, in a simple two-country model where each country is subject to labour-supply, cost-push and money-demand shocks, the optimal coordinated policy can be supported by independent national monetary authorities following a policy of flexible inflation targeting. Such a policy minimises a loss function which depends on a weighted sum of producer-price volatility and output-gap volatility. After deriving the theoretically optimal policy regime, the paper compares a number of possible simple targeting rules. It is found that money-supply targeting and fixed exchange rates are in general dominated by either consumer-price targeting, producer-price targeting or nominal-income targeting. When the variance of cost-push shocks is small, strict producer-price targeting is found to be best of all the regimes considered. For intermediate levels of the variance of cost-push shocks, strict consumer-price targeting is best. For high levels of the variance of cost-push shocks nominal-income targeting is best.

The model presented in this paper is restricted in a number of respects. Firstly, there are no real demand shocks. The international macroeconomics literature has previously emphasised the importance of real demand shocks for the choice of exchange rate regime. The introduction of real demand shocks is therefore an obvious way to develop the model and analysis presented in this paper. Secondly, the utility function used in this paper is restricted in the sense that utility is logarithmic in consumption and the elasticity of substitution between home and foreign goods is fixed at unity. The former restriction implies a very particular level of risk aversion while the latter restriction ties down the expenditure switching effect. Both the degree of risk aversion and the strength of the expenditure switching effect have important implications for the welfare effects of monetary policy and the choice of monetary policy regime.[22] Again these issues suggest interesting ways to develop the model and analysis presented in this paper.

[22] Devereux and Engel (1998, 2000) consider the implication of risk aversion for the welfare effects of monetary policy in a two-country model where there are no cost-push shocks. Sutherland (2002) considers the implications of the expenditure switching effect in a small open economy model where there are no cost-push shocks.

Appendix

Optimal Price Setting

The price setting problem facing flexible-price producer z is the following:

$$MaxU(z) = \log C(z) + \log\left(\frac{M}{P}\right) - \frac{K}{\mu} y_2^{\mu}(z) \tag{43}$$

subject to

$$PC(z) = (1+\alpha)\, p_{H,2}(z)\, y_2(z) + M_0 - M - T \tag{44}$$

$$y_2(z) = c_{H,2}(z) + c^*_{H,2}(z) = \frac{1}{1-\psi}\left(C_{H,2} + C^*_{H,2}\right)\left(\frac{p_{H,2}(z)}{P_{H,2}}\right)^{-\phi} \tag{45}$$

The first order condition with respect to $p_{H,2}(z)$ is

$$(1+\alpha)\frac{y_2(z)}{PC(z)} - \phi\left[(1+\alpha)\frac{p_{H,2}(z)}{PC(z)} - K y_2^{\mu-1}(z)\right]\frac{y_2(z)}{p_{H,2}(z)} = 0 \tag{46}$$

In equilibrium all flexible-price agents choose the same price and consumption level so

$$(1+\alpha)\frac{Y_2}{PC} - \phi\left[(1+\alpha)\frac{P_{H,2}}{PC} - K Y_2^{\mu-1}\right]\frac{Y_2}{P_{H,2}} = 0 \tag{47}$$

where

$$Y_2 = \frac{1}{1-\psi}\left(C_{H,2} + C^*_{H,2}\right) = Y\left(\frac{P_{H,2}}{P_H}\right)^{-1} \tag{48}$$

where

$$Y = C_H + C^*_H = C\left(\frac{P_H}{P}\right)^{-1} \tag{49}$$

Rearranging yields the expression in the main text.

The price setting problem facing fixed-price producer z is the following:

$$MaxU(z) = E\left\{\log C(z) + \log\left(\frac{M}{P}\right) - \frac{K}{\mu} y_1^{\mu}(z)\right\} \tag{50}$$

subject to

$$PC(z) = (1+\alpha)\, p_{H,1}(z)\, y_1(z) + M_0 - M - T \tag{51}$$

$$y_1(z) = c_{H,1}(z) + c^*_{H,1}(z) = \frac{1}{\psi}\left(C_{H,1} + C^*_{H,1}\right)\left(\frac{p_{H,1}(z)}{P_{H,1}}\right)^{-\phi} \tag{52}$$

The first order condition with respect to $p_{H,1}(z)$ is

$$E\left\{(1+\alpha)\frac{y_1(z)}{PC(z)} - \phi\left[(1+\alpha)\frac{p_{H,1}(z)}{PC(z)} - K y_1^{\mu-1}(z)\right]\frac{y_1(z)}{p_{H,1}(z)}\right\} = 0 \tag{53}$$

In equilibrium all fixed-price agents choose the same price and consumption level so

$$E\left\{(1+\alpha)\frac{Y_1}{PC}-\phi\left[(1+\alpha)\frac{P_{H,1}}{PC}-KY_1^{\mu-1}\right]\frac{Y_1}{P_{H,1}}\right\}=0 \tag{54}$$

where

$$Y_1=\frac{1}{\psi}\left(C_{H,1}+C^*_{H,1}\right)=Y\left(\frac{P_{H,1}}{P_H}\right)^{-1} \tag{55}$$

Rearranging yields the expression given in the main text.

Simplifying the Welfare Function

Notice that (30) can be rewritten as follows

$$\begin{aligned}\Omega_D &= -\frac{\psi\mu}{2}\left\{Var\left[\hat{Y}_1+\frac{\hat{K}}{\mu}\right]+Var\left[\hat{Y}^*_1+\frac{\hat{K}^*}{\mu}\right]\right\}\\ &\quad -\frac{\psi\mu}{2}\left\{\left(E\left[\hat{Y}_1\right]\right)^2+\left(E\left[\hat{Y}^*_1\right]\right)^2\right\}+tip+O\left(\|\xi\|^3\right)\end{aligned} \tag{56}$$

It is possible to derive the following expressions for $E\left[\hat{Y}_1\right]$ and $E\left[\hat{Y}^*_1\right]$

$$E\left[\hat{Y}_1\right]=-\frac{\mu Var\left[\hat{Y}_1+\frac{\hat{K}}{\mu}\right]-\sigma_A^2}{2} \tag{57}$$

$$E\left[\hat{Y}^*_1\right]=-\frac{\mu Var\left[\hat{Y}^*_1+\frac{\hat{K}^*}{\mu}\right]-\sigma_{A^*}^2}{2} \tag{58}$$

Notice that all the equations of the model are linear in logs and all the shocks are log-normal. It therefore follows that all the endogenous variables in the model are also log-normal. Using these facts, and the above expressions for $E\left[\hat{Y}_1\right]$ and $E\left[\hat{Y}^*_1\right]$, it is possible to expand the residual term $O\left(\|\xi\|^3\right)$ in (56) and show that

$$\frac{\psi\mu}{2}\left\{\left(E\left[\hat{Y}_1\right]\right)^2+\left(E\left[\hat{Y}^*_1\right]\right)^2\right\}-O\left(\|\xi\|^3\right)=\frac{2\psi}{\mu}\left(1+\frac{\sigma_A^2}{2}-Exp\left[\frac{\sigma_A^2}{2}\right]\right) \tag{59}$$

The expression on the right hand side of (59) does not depend on policy variables so it can be absorbed into the *tip* term in the welfare expression. Thus expression (31) in the main text is derived.

Welfare Levels

1. Money targeting: Money targeting implies $\hat{M}=\hat{M}^*=0$ so $\hat{Y}_1=-\hat{\chi}-\hat{P}_{H,1}$ and $\hat{Y}^*_1=-\hat{\chi}^*-\hat{P}^*_{F,1}$. Substituting into (31) yields the following expression for welfare

$$\Omega_D=-\frac{\psi\left(\sigma_K^2+\mu^2\sigma_\chi^2\right)}{\mu}+tip \tag{60}$$

2. Producer-price targeting: From (35) and (36) it follows that producer-price targeting implies the following monetary rules

$$\hat{M} = \hat{\chi} - \frac{\hat{A} + \hat{K}}{\mu},\ \hat{M}^* = \hat{\chi}^* - \frac{\hat{A}^* + \hat{K}^*}{\mu} \tag{61}$$

These monetary rules imply

$$\hat{Y}_1 = -\frac{\hat{A} + \hat{K}}{\mu},\ \hat{Y}_2 = -\frac{\hat{A}^* + \hat{K}^*}{\mu} \tag{62}$$

When substituted into (31) the following expression for welfare is obtained

$$\Omega_D = -\frac{\psi\sigma_A^2}{\mu} + tip \tag{63}$$

3. Consumer-price targeting: Targeting the consumer-price index in each country implies

$$\hat{P} = \nu\hat{P}_H + (1-\nu)\left(\hat{P}_F + \hat{S}\right) = 0 \tag{64}$$

$$\hat{P}^* = \nu\hat{P}_F^* + (1-\nu)\left(\hat{P}_H - \hat{S}\right) = 0 \tag{65}$$

Using (35) and (36) these two equations imply

$$\hat{M} = \hat{\chi} - \frac{2B-\gamma}{2B}\left(\frac{\hat{A} + \hat{K}}{\mu}\right) - \frac{\gamma}{2B}\left(\frac{\hat{A}^* + \hat{K}^*}{\mu}\right) \tag{66}$$

$$\hat{M}^* = \hat{\chi}^* - \frac{\gamma}{2B}\left(\frac{\hat{A} + \hat{K}}{\mu}\right) - \frac{2B-\gamma}{2B}\left(\frac{\hat{A}^* + \hat{K}^*}{\mu}\right) \tag{67}$$

where $B = 1 - \psi(1-\gamma)$. When substituted into (31) the following expression for welfare is obtained

$$\Omega_D = -\frac{\psi\left[(1-\rho)\gamma^2\sigma_K^2 + \left[2B^2 - (2B-\gamma)(1-\rho)\gamma\right]\sigma_A^2\right]}{2\mu B^2} + tip \tag{68}$$

4. Nominal-income targeting: Nominal-income targeting implies $\hat{M} = \hat{\chi}$ and $\hat{M}^* = \hat{\chi}$ so, from (32) and (33) it is apparent that $\hat{Y}_1 = -\hat{P}_{H,1}$ and $\hat{Y}_1^* = -\hat{P}_{F,1}^*$. Substituting into (31) yields the following expression for welfare

$$\Omega_D = -\frac{\psi\sigma_K^2}{\mu} + tip \tag{69}$$

5. Symmetric fixed nominal exchange rate: A fixed nominal exchange rate implies

$$\hat{M} - \hat{\chi} = \hat{M}^* - \hat{\chi}^* \tag{70}$$

From (35) and (36) it follows that targeting the aggregate world consumer price index implies

$$\frac{\hat{A} + \hat{K}}{\mu} + \hat{M} - \hat{\chi} + \frac{\hat{A}^* + \hat{K}^*}{\mu} + \hat{M}^* - \hat{\chi}^* = 0 \tag{71}$$

These two equations imply

$$\hat{M} = \hat{M}^* = \frac{1}{2}\left(\hat{\chi} + \hat{\chi}^* + \frac{\hat{A} + \hat{K}}{\mu} + \frac{\hat{A}^* + \hat{K}^*}{\mu}\right) \tag{72}$$

When substituted into (31) the following expression for welfare is obtained

$$\Omega_D = -\frac{\psi\left[(1-\rho)\sigma_K^2 + (1+\rho)\sigma_A^2\right]}{2\mu} + tip \tag{73}$$

6. Fixed exchange rate/foreign money targeting: Foreign money targeting implies $M^* = 0$ and a fixed nominal exchange rate implies $\hat{M} = \hat{\chi} - \hat{\chi}^*$. So $\hat{Y}_1 = \hat{\chi}^* - \hat{P}_{H,1}$ and $\hat{Y}_1^* = -\hat{\chi}^* - \hat{P}_{F,1}^*$. Substituting into (31) yields the following expression for welfare

$$\Omega_D = -\psi\left(\sigma_K^2 + \mu^2\sigma_\chi^2\right) + tip \tag{74}$$

7. Fixed exchange rate/foreign producer-price targeting: Foreign producer-price targeting implies

$$M^* = \hat{\chi}^* - \frac{\hat{A}^* + \hat{K}^*}{\mu} \tag{75}$$

A fixed nominal exchange rate implies $\hat{M} = \hat{\chi} - \hat{\chi}^* + M^*$. So

$$\hat{Y}_1 = \hat{Y}_2 = -\frac{\hat{A}^* + \hat{K}^*}{\mu} \tag{76}$$

Substituting into (31) yields the following expression for welfare

$$\Omega_D = -\frac{\psi\left[(1-\rho)\sigma_K^2 + \sigma_A^2\right]}{\mu} + tip \tag{77}$$

8. Fixed exchange rate/foreign consumer-price targeting: Foreign consumer-price targeting implies

$$\hat{P}^* = \nu\hat{P}_F^* + (1-\nu)\left(\hat{P}_H - \hat{S}\right) = 0 \tag{78}$$

and a fixed nominal exchange rate implies $\hat{M} = \hat{\chi} - \hat{\chi}^* + M^*$. Solving for output levels yields

$$\hat{Y}_1 = \hat{Y}_2 = -\frac{\gamma\left(\hat{A} + \hat{K}\right) - (2-\gamma)\left(\hat{A}^* + \hat{K}^*\right)}{2\mu} \tag{79}$$

Substituting into (31) yields the following expression for welfare

$$\Omega_D = -\frac{\psi\left[(1-\rho)\left[2-\gamma(2-\gamma)\right]\sigma_K^2 + \left[2-(1-\rho)\gamma(2-\gamma)\right]\sigma_A^2\right]}{2\mu} + tip \tag{80}$$

References

[1] Aoki, Kosuke (2001) "Optimal Monetary Policy Responses to Relative Price Changes" *Journal of Monetary Economics*, 48, 55-80.

[2] Bacchetta, Philippe and Eric van Wincoop (2000) "Does Exchange Rate Stability Increase Trade and Welfare?" *American Economic Review*, 90, 1093-1109.

[3] Benigno, Gianluca and Pierpaolo Benigno (2001) "Price Stability as a Nash Equilibrium in Monetary Open Economy Models" CEPR Discussion Paper No 2757.

[4] Benigno, Gianluca and Pierpaolo Benigno (2001) "Implementing Monetary Cooperation through Inflation Targeting" unpublished manuscript, Bank of England and New York University.

[5] Calvo, Guillermo A (1983) "Staggered Prices in a Utility-Maximising Framework" *Journal of Monetary Economics*, 12, 383-398.

[6] Clarida, Richard H, Jordi Gali and Mark Gertler (2001a) "Optimal Monetary Policy in Open versus Closed Economies: An Integrated Approach" *American Economic Review (Papers and Proceedings)*, 91, 248-252.

[7] Clarida, Richard H, Jordi Gali and Mark Gertler (200b) "A Simple Framework for International Monetary Policy Analysis" unpublished manuscript, Columbia University, Pompeu-Fabra and New York University.

[8] Corsetti, Giancarlo and Paolo Pesenti (2001a) "Welfare and Macroeconomic Interdependence" *Quarterly Journal of Economics*, 116, 421-446.

[9] Corsetti, Giancarlo and Paolo Pesenti (2001b) "International Dimensions of Optimal Monetary Policy" NBER Working Paper No 8230.

[10] Devereux, Michael B and Charles Engel (1998) "Fixed versus Floating Exchange Rates: How Price Setting Affects the Optimal Choice of Exchange Rate Regime" NBER Working paper 6867.

[11] Devereux, Michael B and Charles Engel (2000) "Monetary Policy in an Open Economy Revisited: Price Setting and Exchange Rate Flexibility" NBER Working Paper No 7665.

[12] Engel, Charles (2001) "The Responsiveness of Consumer Prices to Exchange Rates and the Implications for Exchange Rate policy" unpublished manuscript, University of Wisconsin.

[13] Goodfriend, Marvin and Robert G King (2001) "The Case for Price Stability" NBER Working Paper No 8423.

[14] Jensen, Henrik (1999) "Targeting Nominal Income Growth of Inflation?" unpublished manuscript, University of Copenhagen.

[15] King, Robert G and Alexander L Wolman (1999) "What Should the Monetary Authority Do When Prices are Sticky?" in John B Taylor (ed) *Monetary Policy Rules*, University of Chicago Press, Chicago.

[16] Kim, Jinill and Sunghyun H Kim (2000) "Spurious Welfare Reversals in International Business Cycle Models" unpublished manuscript, University of Virginia (forthcoming in the *Journal of International Economics*).

[17] Lane, Philip (2001) "The New Open Economy Macroeconomics: A Survey" *Journal of International Economics*, 54-235-266.

[18] McCallum, Bennett T and Edward Nelson (1999) "Nominal Income Targeting in an Open-Economy Optimizing Model," *Journal of Monetary Economics*, 43, 553-578.

[19] Obstfeld, Maurice and Kenneth Rogoff (1995) "Exchange Rate Dynamics Redux" *Journal of Political Economy*, 103, 624-660.

[20] Obstfeld, Maurice and Kenneth Rogoff (1998) "Risk and Exchange Rates" NBER Working paper 6694.

[21] Obstfeld, Maurice and Kenneth Rogoff (2000) "New Directions in Stochastic Open Economy Models" *Journal of International Economics*, 50, 117-154.

[22] Obstfeld, Maurice and Kenneth Rogoff (2002) "Global Implications of Self-Oriented National Monetary Rules" *Quarterly Journal of Economics*, 117, 503-536.

[23] Rankin, Neil (1998) "Nominal Rigidity and Monetary Uncertainty" *European Economic Review*, 42, 185-200.

[24] Schmitt-Grohé, Stephanie and Martin Uribe (2001) "Solving Dynamic General Equilibrium Models using a Second-Order Approximation to the Policy Function" CEPR Discussion Paper No 2963.

[25] Sims, Christopher (2000) "Second-Order Accurate Solutions of Discrete Time Dynamic Equilibrium Models" unpublished manuscript, Princeton University.

[26] Smets, Frank and Raf Wouters (2001) "Openness, Imperfect Exchange Rate Pass Through and Monetary Policy" unpublished manuscript, European Central Bank.

[27] Sutherland, Alan J (2000) "Inflation Targeting in a Small Open Economy" CEPR Discussion Paper 2726.

[28] Sutherland, Alan J (2001a) "Imperfect Pass-Through and the Welfare Effects of Exchange Rate Variability" unpublished manuscript, University of St Andrews.

[29] Sutherland, Alan J (2001b) "A Simple Second-Order Solution Method for Dynamic General Equilibrium Models" unpublished manuscript, University of St Andrews.

[30] Sutherland, Alan J (2002) "The Expenditure Switching Effect, Welfare and Monetary Policy in a Small Open Economy" unpublished manuscript, University of St Andrews.

[31] Svensson, Lars E O (1999) "Inflation Targeting as a Monetary Policy Rule" *Journal of Monetary Economics*, 43, 607-654.

[32] Svensson, Lars E O (2000) "Open-economy Inflation Targeting" *Journal of International Economics*, 50, 155-184.

[33] Woodford, Michael (2001) "Inflation Stabilisation and Welfare" NBER Working Paper No 8071.

Figure 1: Effect of Psi on X1 and X2

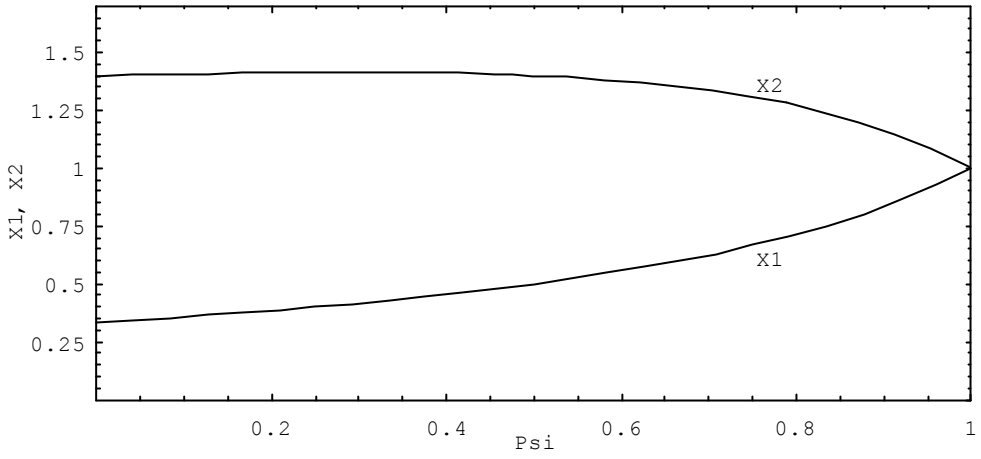


Figure 2: Effect of Gamma on X1 and X2

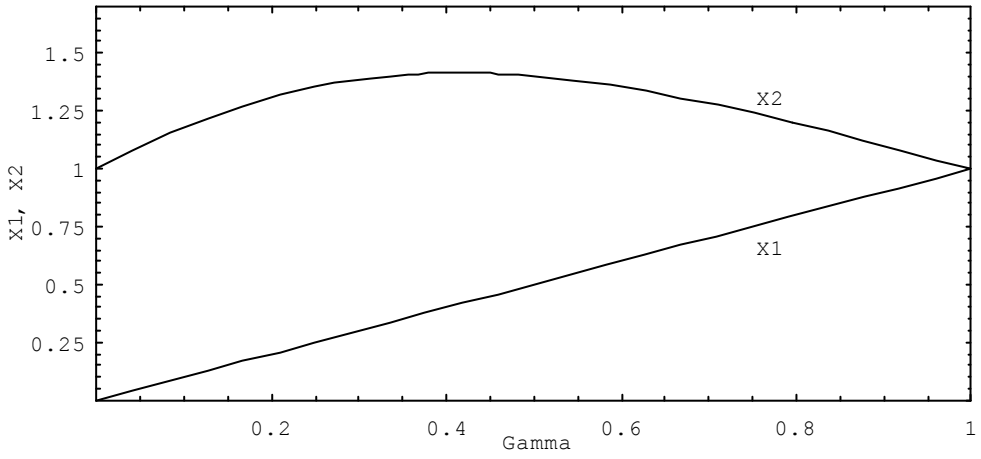
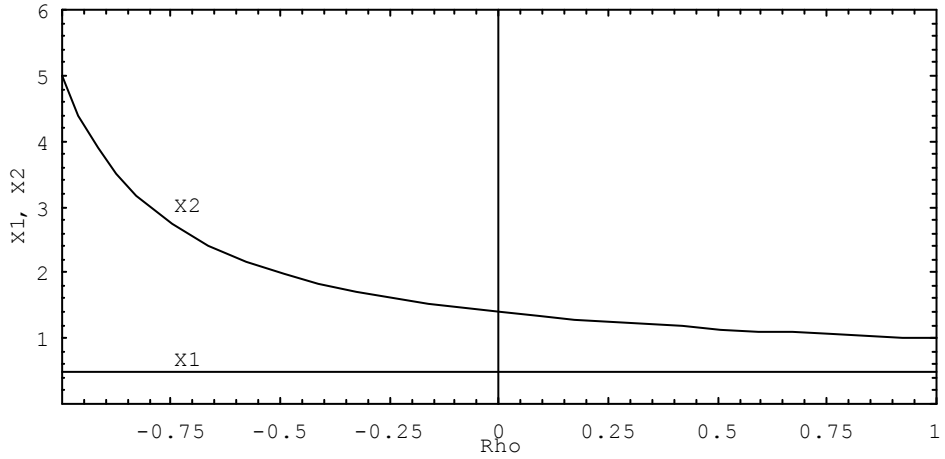


Figure 3: Effect of Rho on X1 and X2



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