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International spillover effects and monetary policy activism

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Abstract

This paper examines how the preferences of a large economy's central bank affect the trade-off between output and inflation volatility faced by the central bank of a small open economy by analysing the impact of a global cost-push shock. We demonstrate that under the assumption of producer currency pricing, the trade-off faced by the small open economy is likely to worsen as the foreign central bank becomes more focused on output stabilisation relative to inflation stabilisation; but the opposite is true in the case of local currency pricing.

Key words: Open economy, policy trade-offs, producer versus local currency pricing.

JEL classification: E58, F41, F42.

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Contents

Summary 3

1 Introduction 5

2 The model 7

2.1 Policy objectives 9

3 Results 10

3.1 Case 1: Producer currency pricing and goods substitutes in the utility 11

3.2 Case 2: Producer currency pricing and goods complements in the utility 13

3.3 Case 3: Local currency pricing and goods substitutes in the utility 15

3.4 Sticky wages 19

4 Discussion 19

5 Conclusions 21

Appendix 23

Producer currency pricing (PCP) versus local currency pricing (LCP) 23

References 25

Summary

When several countries are hit by the same global shock, how do other central banks' reactions to that shock affect the trade-off between inflation and output stabilisation faced by a central bank of a small open economy? This is very pertinent in the United Kingdom's case, a relatively small country with some large trading partners.

Such a country is potentially affected by foreign monetary policy through a demand channel as well as a supply channel. The demand channel works as follows: by stimulating global demand, an expansionary monetary policy abroad can potentially lead to higher demand for UK goods (an aggregate demand effect). But a foreign monetary expansion also tends to lead to an appreciation of sterling, which may dampen demand for UK goods (an expenditure-switching effect). The overall effect on the demand for UK goods of a foreign monetary expansion therefore depends on the strength of the aggregate demand effect relative to the expenditure-switching effect. Foreign monetary policy also affects UK supply. This is because foreign monetary policy affects the terms of trade, and shifts in the terms of trade can affect workers' incentives to work for a given real wage. On the one hand, a deterioration in the terms of trade makes workers feel poorer, thus inducing them to work harder (the 'income effect'). On the other hand, it also reduces the amount of consumption which they can obtain by working an additional hour, and this diminishes the incentives to work (the 'substitution effect'). Depending on the preferences of households either the income or substitution effect may dominate.

Thus in this paper we examine how the preferences of a large economy's central bank (such as the European Central Bank or the Federal Reserve Board) affect the trade-off between output and inflation volatility faced by a central bank of a small open economy (such as the Bank of England). We use a New Keynesian model of a small open economy (where there is a degree of price stickiness). We refer to the small open economy as 'Home', and the large open economy as 'Foreign'. To conduct this analysis, we examine the impact of a global 'cost-push shock', eg, a rise in the price of oil, raising the cost of production. This shock will generate an output-inflation trade-off both for the Home and the Foreign central bank.

The specific question which we seek to address is: does it make it harder for the Home central

bank to bring down inflation without causing a large contraction of output when the Foreign central bank is 'dovish', and is hesitant to bring down inflation quickly? We demonstrate that the answer to this question is not straightforward. We find that the impact of a more dovish Foreign central bank on the trade-off faced by the Home central bank depends on two key assumptions of the model: it depends on the currency in which exports are denominated, and it depends on the substitutability between goods produced in the Home and Foreign countries. The choice of invoicing currency is important, as it determines how Foreign monetary policy affects Home's terms of trade. The substitutability between goods determines the extent to which demand switches between Home and Foreign goods following a change in relative prices, and it determines how Home labour supply responds to fluctuations in the terms of trade. When exports are denominated in the producer's currency ('producer currency pricing'), the trade-off faced by the Home economy is likely to worsen as the Foreign central bank becomes more focused on output stabilisation. But the opposite tend to be true in the case of local currency pricing.

1 Introduction

Over the period from about 2003 to 2008 the world experienced a sharp rise in the price of oil and other commodities, which put upward pressure on inflation across the globe as discussed by IMF (2008). Moreover, as documented by IMF (2009), output growth has contracted sharply in most countries following the adverse shock to the international financial system, which gained momentum during the course of 2008. This has posed challenges for central banks that on the one hand wish to stimulate growth while at the same time ensuring that inflation expectations remain anchored. Since central banks differ in terms of their preferences for stabilising output and inflation, monetary policy has responded differently to this challenge across countries.[1]

When several countries are hit by the same global shock, how do other central banks' reactions to that shock affect the trade-off between inflation and output stabilisation faced by a central bank of a small open economy? A relatively small, open economy, such as the United Kingdom, is potentially affected by foreign monetary policy through a demand channel as well as a supply channel. The demand channel works as follows: by stimulating global demand, an expansionary monetary policy abroad can potentially lead to higher demand for UK goods (aggregate demand effect). But a foreign monetary expansion also tends to lead to an appreciation of sterling, which may dampen demand for UK goods (expenditure-switching effect). The overall effect on the demand for UK goods of a foreign monetary expansion therefore depends on the strength of the aggregate demand effect relative to the expenditure-switching effect.

Foreign monetary policy also affects UK supply. This is because foreign monetary policy affects the terms of trade, and shifts in the terms of trade can affect workers' incentives to work for a given real wage. On the one hand, a deterioration in the terms of trade makes workers feel poorer, thus inducing them to work harder (income effect). On the other hand, it also reduces the amount of consumption which they can obtain by working an additional hour, and this diminishes the incentives to work (substitution effect). Depending on the preferences of households either the income effect or the substitution effect may dominate.

Since the monetary policy of central banks in the United Kingdom's large trading partners, such as the European Central Bank (ECB) and the Federal Reserve (Fed), can influence demand and

[1] The differences in monetary policy responses may also reflect the fact that the shocks have not affected all countries to the same extent.

supply in the United Kingdom, their preferences can impact on the trade-off between inflation and output volatility faced by the Bank of England. This paper examines how the preference of a large economy's central bank affects the trade-off between output and inflation volatility faced by a central bank of a small open economy, using a New Keynesian model of a small open economy along the lines of Gali and Monacelli (2005) and De Paoli (2009). In what follows, we refer to the small open economy as 'Home', and the large open economy as 'Foreign'. To conduct this analysis, we examine the impact of a global cost-push shock, which generates an output-inflation trade-off both for the Home and the Foreign central bank.

The specific question which this paper seeks to address is: does it make it harder for the Home central bank to bring down inflation without causing a large contraction of output when the Foreign central bank is 'dovish', and is hesitant to bring down inflation quickly? As we will demonstrate, the answer to this question is non-trivial. We find that the impact of a more 'dovish' Foreign central bank on the trade-off faced by the Home central bank depends on two key assumptions of the model: it depends on the currency in which exports are denominated, and it depends on the substitutability between goods produced in Home and Foreign. The choice of invoicing currency is important since it determines how Foreign monetary policy affects Home's terms of trade. The substitutability between goods determines the extent to which demand switches between Home and Foreign goods following a change in relative prices, and it determines how Home labour supply responds to fluctuations in the terms of trade.

Under the assumption of producer currency pricing (PCP: ie, where products are priced in the currency of the exporters), we find that as the Foreign central bank becomes more dovish – ie it places less weight on stabilising inflation relative to stabilising output in its objective function – the Home central bank is likely to be facing a more adverse inflation-output trade-off in the sense that for a given level of output volatility it has to tolerate greater volatility of inflation. But under local currency pricing (LCP: ie, where products are priced in the currency of consumers), assuming that the prices set by Home exporters are sufficiently sticky, the Home central bank's trade-off improves as the Foreign central bank becomes more dovish.

The rest of the paper is organised as follows. Section 2 outlines the small open economy model used for the analysis. Section 3 discusses the key results of our analysis. Section 4 discusses the implications of our results and Section 5 concludes.

2 The model

The analysis is conducted within a dynamic two-country general equilibrium model, which consists of 'Home' (indexed by H) and 'Foreign' (indexed by F). In what follows, all Foreign variables are denoted by *. Representative households in each country supply labour to monopolistically competitive firms producing differentiated goods, and consume goods produced both at Home and in Foreign. Wages are assumed to be fully flexible, but prices are assumed to be sticky as in Calvo (1983). All goods are tradable, but the existence of a home bias in preferences allows us to calibrate the degree of openness of the Home country. We adopt the approach of De Paoli (2009), which first solves for the equilibrium of the two-country model, and then takes the limit of the Home's size to zero. Consequently, the Home economy becomes a small open economy whereas the Foreign economy behaves like a closed economy: while Foreign monetary policy affects Home, the reverse is not true, because Foreign households consume a tiny amount of Home goods. The model is in the class of the cashless-limiting economies, see eg Woodford (2003). Here, we only present a summary of the model's equilibrium conditions in log-linearised form. For the derivation of these equations, see Appendix A of De Paoli (2009).

As a starting point we assume that goods are priced in the producer's currency, so that any changes in the nominal exchange rate are immediately and fully passed through to the domestic price of imports. Thus, a depreciation of Home currency against Foreign currency will lead to an immediate rise in Home goods price in the Foreign market, and an immediate fall in Foreign goods price in the Home market. Under producer currency pricing, the model's equilibrium conditions for Home economy can be characterised by the equations presented below. All variables are expressed in log deviations from steady state, ie $\widehat{X} = \frac{X-\overline{X}}{\overline{X}}$.

$$\widehat{\pi}_{H,t} = k(\rho\widehat{C}_t + \eta\widehat{Y}_t + \lambda\widehat{ToT}_t + \widehat{\mu}_t) + \beta\widehat{\pi}_{H,t+1} \quad \textbf{(1)}$$

$$\widehat{Y}_t = (1-\lambda)\widehat{C}_t + \lambda\widehat{C}^*_t + \theta\lambda\,(2-\lambda)\,\widehat{ToT}_t \quad \textbf{(2)}$$

$$\widehat{C}_t = \widehat{C}^*_t + \frac{1}{\rho}\widehat{RS}_t \quad \textbf{(3)}$$

$$\widehat{\pi}_t = (1-\lambda)\widehat{\pi}_{H,t} + \lambda\widehat{\pi}_{F,t} \quad \textbf{(4)}$$

$$\widehat{\pi}_{F,t} = \widehat{\pi}^*_t + \Delta\widehat{S}_t \quad \textbf{(5)}$$

$$\Delta\widehat{RS}_t = \Delta\widehat{S}_t + \widehat{\pi}^*_t - \widehat{\pi}_t \quad \textbf{(6)}$$

$$\Delta \widehat{ToT}_t = \Delta \widehat{S}_t + \pi^*_t - \widehat{\pi}^H_t \quad \textbf{(7)}$$

$$\widehat{ToT}_t = \frac{1}{1-\lambda} \widehat{RS}_t \quad \textbf{(8)}$$

The variables $\widehat{C}_t$ and $\widehat{C}^*_t$ denote Home and Foreign consumption, $\widehat{Y}_t$ denotes Home output, $\widehat{ToT}_t$ represents the terms of trade, $\widehat{RS}_t$ denotes the real exchange rate and $\Delta \widehat{RS}_t$ denotes its change from one period to the next (a rise in $\widehat{RS}_t$ indicates a Home depreciation). Similarly $\Delta \widehat{S}_t$ represents the change in the nominal exchange rate. $\widehat{\pi}_t$ denotes Home consumer price inflation while $\widehat{\pi}^*_t$ is Foreign consumer price inflation (which dynamics are defined by **(9)**), and $\widehat{\pi}^H_t$ denotes Home producer price inflation. The exogenous global cost-push shock is captured by $\widehat{\mu}_t$, which is the wedge between marginal utility of consumption and marginal disutility of production both in Home and Foreign. This is an inefficient shock which increases inflation both in Home and Foreign and creates a trade-off for the central banks between stabilising output and inflation. The remaining parameters are described in Table A below.

Equation **(1)** characterises aggregate supply. Differently from the closed economy, Home inflation depends not only on real marginal cost but also on the terms of trade (the relative price of Foreign towards Home goods). Equation **(2)** describes aggregate demand. Condition **(3)** holds under the assumption of complete financial markets, which allows optimal risk-sharing between Home and Foreign consumers. Consumer price inflation **(4)** is a weighted sum of Home producer price inflation and import price inflation. Under the assumption of producer currency pricing, import price inflation **(5)** is the sum of Foreign producer price inflation and the change in the nominal exchange rate. The system is closed by defining the change in the real exchange rate **(6)** as the sum of the change in the nominal exchange and difference between Foreign and Home consumer price inflation, and defining the change in the terms of trade **(7)** as the sum of the change in the nominal exchange rate and the difference between Foreign and Home producer price inflation. This implies that the terms of trade will be proportional to the real exchange rate, see **(8)**.

By taking the limit of the Home economy's size to zero, the Foreign economy is essentially a closed economy. Since Foreign households consume a minimal amount of Home goods, consumer price inflation coincides with producer price inflation in the Foreign economy. The Foreign economy is therefore characterised by the familiar New Keynesian Phillips Curve:

$$\widehat{\pi}^*_t = k^*((\rho + \eta)\widehat{Y}^*_t + \widehat{\mu}_t) + \beta \widehat{\pi}^*_{t+1} \quad \textbf{(9)}$$

Table A: Model parameters

Intertemporal elasticity of substitution (ρ^{-1})	Scenario dependent
Intratemporal elasticity of substitution (θ)	Scenario dependent
Frisch elasticity of labour supply (η^{-1})	0.47^{-1}
Degree of openness (λ)	0.3
Subjective discount factor (β)	0.99
Elasticity of substitution across the differentiated products (σ)	10
Probability of not being able to reset price (α)	0.66
$k = (1-\alpha\beta)(1-\alpha)/\alpha(1+\sigma\eta)$	
$k^* = (1-\alpha^*\beta)(1-\alpha^*)/\alpha^*(1+\sigma\eta)$	

where $\widehat{\pi}_t^*$ denotes Foreign consumer price inflation and $\widehat{Y}_t^*$ denotes Foreign output. We assume that the Foreign economy is hit by the same cost-push shock as the Home economy, in order to capture the recent worsening of the inflation-output trade-off across many countries. This means that $\widehat{\mu}_t$ is the same for both countries. The model parameters and baseline calibration are outlined in Table A.

2.1 Policy objectives

We assume that the objective of monetary policy is to stabilise a weighted average of the squared deviations of (consumer price) inflation and output from steady state.[2] So the loss functions of the Home and Foreign central banks, respectively, are given by:

$$L = \sum_{t=0}^{\infty} \beta^t \left(\widehat{\pi}_t^2 + \delta \widehat{Y}_t^2\right) \quad ; \quad L^* = \sum_{t=0}^{\infty} \beta^t \left(\widehat{\pi}_t^{*2} + \delta^* \widehat{Y}_t^{*2}\right) \qquad \textbf{(10)}$$

δ and δ^* are the weights that the Home and Foreign central banks place on output stabilisation relative to inflation stabilisation. A central bank with a low δ will be characterised as 'hawkish', whereas a central bank with a high δ is said to be 'dovish'. As argued by Svensson (2003), **(10)** captures well the objectives of an inflation targeting central bank.[3] Since the Home economy is assumed to be of size zero, there is no potential for strategic interaction between the central banks.

[2]Notice that since we study only inefficient shocks, there is no distinction between the variance of output and the variance of the welfare-relevant output gap.

[3]Alternatively, one could have used the welfare-based loss function derived by De Paoli (2009). We find the *ad hoc* loss function more convenient for the analysis in this paper.

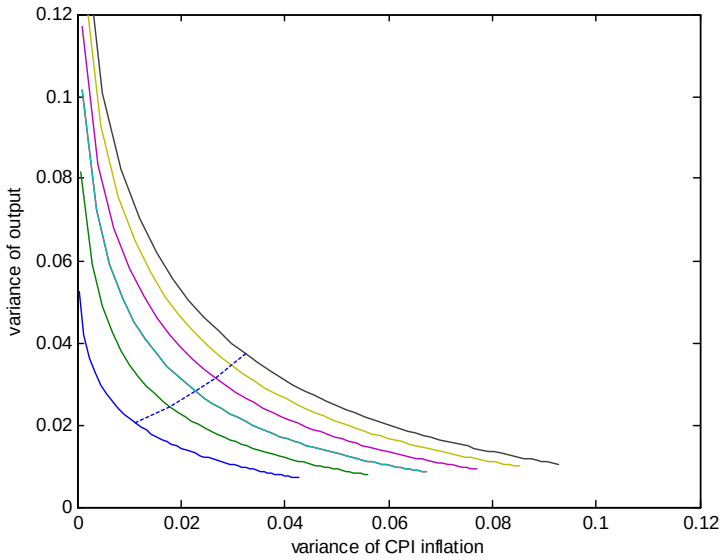
3 Results

We examine the policy trade-off facing the Home central bank when both Home and Foreign are hit by the same 'global' cost-push shock. The shock increases inflation and reduces output to an inefficient level in both countries. The policy trade-off faced by the Home central bank can be summarised in the form of a Taylor frontier. A Taylor frontier plots the combinations of inflation and output volatility that can be achieved by the Home central bank given a set of assumptions about exogenous shocks and the Foreign central bank's policy. The Home central bank will choose a particular point along the Taylor frontier depending on the weight it places on output stabilisation in its loss function, δ.

Does the trade-off facing the Home central bank improve or worsen if the Foreign central bank becomes more dovish? To address this question, we construct the Taylor frontiers faced by the Home central bank under different assumptions about the Foreign central bank's preferences. If a rise in δ^* shifts the Home central bank's Taylor frontier inwards, it implies that the trade-off facing the Home central bank improves as the Foreign central bank becomes more dovish. Conversely, if a rise in δ^* shifts the Home central bank's Taylor frontier outwards, it means that the trade-off facing the Home central bank worsens as the Foreign central bank becomes more dovish.

As we will demonstrate below, the direction in which a rise in δ^* shifts the Home central bank's Taylor frontier depends on two factors. First, it depends on whether Home and Foreign goods are what in technical terms is referred to as **substitutes or complements in the utility**, see eg Corsetti and Pesenti (2001). Home and Foreign goods are substitutes (complements) in the utility, ie the marginal utility of one good decreases (increases) with the consumption of another good, when the intratemporal elasticity of substitution is higher (lower) than the intertemporal elasticity of substitution (analytically when: $\rho\theta > 1$ ($\rho\theta < 1$)). Second, the effect on the Home central bank's Taylor frontier depends on whether exports are priced in producers' currency (producer currency pricing) or in consumers' currency (local currency pricing). In what follows, we examine these cases in turn.

Chart 1: Home Taylor frontier under producer currency pricing and $\rho\theta > 1$



3.1 Case 1: Producer currency pricing and goods substitutes in the utility

In this scenario we set $\theta = 3$ and $\rho = 2.5$, so that Home and Foreign goods are substitutes in the utility ($\rho\theta > 1$). The persistence of the global cost-push shock $\widehat{\mu}_t$ is assumed to be 0.99. The remaining parameters are calibrated according to Table A.

Chart 1 plots the Home Taylor frontiers under this scenario for different values of δ^*. The blue line represents the Home Taylor frontier when the Foreign central bank is most 'hawkish' ($\delta^* = 0.05$, which corresponds to the weight in the utility-based loss function of the closed economy of Woodford (2003)), whereas the black line represents the Home Taylor frontier when the Foreign central bank is most 'dovish' (the weight on output gap in its loss function $\delta^* = 5$). The Home central bank chooses a point on a given Taylor curve depending on its preference, δ: as the Home central bank becomes more and more dovish (ie δ increases), its chosen point will move along each Taylor curve from the left to the right. The dotted line represents variances of output and CPI inflation implied by $\delta = 1$.

Chart 1 shows that as the Foreign central bank becomes more dovish (ie δ^* increases), the Taylor frontier facing the Home country shifts out: so for a given cost-push shock, the Home central

bank has to tolerate greater inflation and output volatility. Why does the trade-off facing the Home central bank worsen as the Foreign central bank becomes more dovish? When the Foreign central bank tightens, this acts on Home inflation and output in a way that directly counters the cost-push shock which reduces output and increases inflation in the Home country. The more hawkish the Foreign central bank, the more aggressively it tightens its monetary policy; so more of the Home cost-push shock is countered without the Home central bank having to do anything.

As studied by Corsetti and Pesenti (2001), a Foreign monetary tightening has two opposing effects on the demand for Home goods and hence on Home output. The demand for Home goods tends to fall as Foreign consumption decreases (aggregate demand effect). On the other hand, a Foreign tightening also leads to a real depreciation of the Home currency and therefore to a terms of trade deterioration. The resulting fall in the foreign price of Home exports increases demand for Home goods, and so its output increases (expenditure-switching effect). Which of these two effects dominates under PCP depends on whether Home and Foreign goods are complements or substitutes in the utility. In this case, as Home and Foreign goods are substitutes in the utility the expenditure-switching effect dominates because even a small shift in the terms of trade induces aggregate demand to switch from Foreign goods to Home goods. Consequently, Foreign demand for Home goods increases and so does Home output.

The impact of a Foreign tightening on Home inflation can be understood by looking at the relationship between real marginal cost and the terms of trade (see Benigno and Benigno (2006)). When the goods are substitutes in the utility, the terms of trade deterioration makes Home workers feel poorer and want to work harder, which pushes down on real wages and inflation. Moreover, imported inflation is lower on account of the Foreign monetary tightening because Foreign inflation is lower. Although the effect on Home prices is partly offset by a larger Home currency depreciation, the effect of lower Foreign inflation dominates when the goods are substitutes in the utility. This is because when the goods are close substitutes, any movements in the terms of trade will be small, and so the impact of exchange rate movements will be modest.[4]

Summing up, the two effects of a cost-push shock – higher inflation and lower output – are partially offset by Foreign monetary tightening. This result can be interpreted as Foreign monetary tightening policy having a prosper-thy-neighbour policy effect on Home (see Corsetti

[4]Also see Woodford (2007) for a discussion of how foreign variables affect domestic labour supply in an open economy.

and Pesenti (2001)). The more dovish the Foreign central bank, the less of this offsetting force the Home economy gets, so the more the cost-push shock affects Home inflation and output: thus its inflation-output trade-off worsens, and the Taylor curve shifts out. In quantitative terms, if we increase δ^* from 1 to 2 , the variance of Home inflation increases by 27% and the variance of Home output by 15% under the assumption that $\delta = 1$.

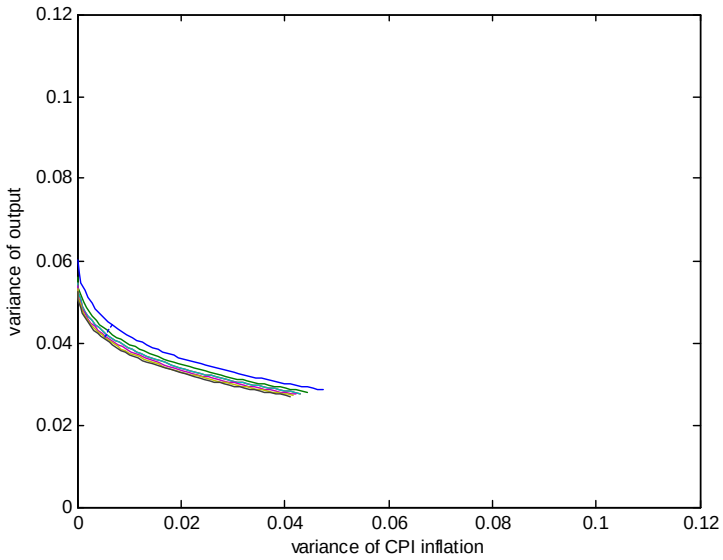
3.2 Case 2: Producer currency pricing and goods complements in the utility

Now assume instead that $\theta = 0.3$ and $\rho = 2.5$, ie the Home and Foreign goods are complements in the utility ($\rho\theta < 1$). Chart 2 plots the Home Taylor frontier under this assumption: as before, the blue line represents the case when $\delta^* = 0.05$ (Foreign central bank is hawkish) while the black line represents the case when $\delta^* = 5$ (Foreign central bank is dovish). Chart 2 shows that when goods are complements in the utility, the result reverses: as the Foreign central bank becomes more dovish (ie δ^* increases), the Home Taylor frontier now shifts in, thus improving the trade-off facing the Home central bank. So in this case the Foreign monetary policy tightening amplifies the cost-push shock from Home's perspective. Home inflation is higher while output is lower.

As before, the Foreign tightening results in lower Foreign consumption and a depreciation of the Home currency. But since Home and Foreign goods are complements, the effect of lower Foreign consumption is to reduce demand for Home goods. So in this case the aggregate demand effect dominates the expenditure-switching effect. This leads to a lower demand for Home goods and smaller Home output.

A terms of trade depreciation now increases real marginal cost and also Home inflation. This happens because lower consumption of Foreign goods reduces the marginal utility of Home goods. As the utility from leisure rises relative to that from consumption, Home workers choose to work less, not more. Import inflation will also increase. When the goods are complements in the utility, movements in the terms of trade tend to be large. The inflationary impact of the deterioration of Home's terms of trade associated with a tightening of the Foreign central bank therefore dominates the effect of lower Foreign inflation. This result can be interpreted as Foreign monetary tightening policy having a beggar-thy-neighbour policy effect on Home (see Corsetti and Pesenti (2001)).

Chart 2: Home Taylor frontier under producer currency pricing and $\rho\theta < 1$



Finally, when the goods are neither substitutes nor complements in the utility (ie when $\rho\theta = 1$), the Foreign central bank's preference has no implications for the inflation-output trade-off facing the Home central bank, because in this special case, Foreign monetary policy has no impact on demand for Home goods (income and substitution effects cancel out). In other words, Home inflation is a function only of Home real marginal cost. So the Home economy is independent of the terms of trade, but its consumption still depends on terms of trade changes.

The finding that under PCP the Home economy would prefer the Foreign central bank to be hawkish when the goods are substitutes and more dovish when the goods are complements is related to a result by Benigno and Benigno (2008). In a two-country model with cost-push shocks they study how the objectives of the national central banks should be designed to maximise the combined welfare of the households in both countries. The authors find that the optimal objective of each of foreign central bank can be represented as a weighted sum of domestic producer price inflation and the output gap. The weights attached to each of the variables depend on the substitutability of home and foreign goods. If the goods are substitutes the central banks should respond more to fluctuations in the output gap relative to the closed economy version of the model whereas the opposite is the case if the goods are complements. This reflects the fact that when the goods are substitutes, a hawkish policy of one country

improves welfare of the other country.

The loss function **(10)** assumes that central banks stabilise consumer price inflation, which is in line with international evidence. However, the literature on optimal monetary policy prescribes that under an assumption of producer currency pricing the correct measure of inflation in the utility-based loss function is producer price inflation (see eg De Paoli (2009)). We have experimented with such an alternative loss function and the results do not change. The direction of the international spillovers stays the same irrespective of the measure of inflation used in the loss function.

3.3 Case 3: Local currency pricing and goods substitutes in the utility

The preceding analysis was conducted under the assumption that prices are sticky in the currency of the producer. Movements in nominal exchange rates are therefore passed through immediately to import prices. This is a useful benchmark, and it is strongly advocated by Obstfeld and Rogoff (2000b) on the basis that it implies that a nominal depreciation is associated with a terms of trade deterioration, which is consistent with the data. But as pointed out by Mussa (1986), the link between changes in exchange rates and changes in national consumer prices is weak empirically. This contradicts one of the key implications of producer currency pricing. As a robustness check we therefore repeat our analysis under the assumption that prices are sticky in the currency of the consumer rather than the producer (local currency pricing).

The model with local currency pricing is essentially a stripped down version of the small open economy model developed by Lipinska (2008). Since the Foreign country is essentially a closed economy, the change in the pricing assumption does not alter the set-up and the equilibrium condition of Foreign, given by **(9)**. But for Home this means several changes.

Since the law of one price does not hold, the relative price of Home to Foreign goods differs between the two countries. Following Benigno (2004) we define T_t and T_t^* to represent the relative price of the imported good in terms of the one produced domestically, expressed in the local currency. The assumption that a Home producer can charge different prices in Home and in Foreign markets implies that the inflation rate of Home-produced goods in the Home market, $\widehat{\pi}_{H,t}$, differs from the inflation rate of Home-produced goods in the Foreign market, $\widehat{\pi}^*_{H,t}$.

Reflecting this, there are two different Phillips curves for Home goods depending on whether they are traded at home or abroad (**(11)** and **(12)**). Home inflation and Home export inflation both depend on real marginal costs and on the relative price of Home to Foreign goods in local currency. Moreover, Home export inflation also depends on the real exchange rate, which stems from the fact that revenues of Home exporters are denominated in Foreign currency and costs are in Home currency. Similarly, as Foreign producers also charge different prices in the two countries, we obtain a separate inflation equation for imports in the Home country, $\widehat{\pi}_{F,t}$ **(13)**. Its dynamics depend not only on Foreign real marginal cost but also on the price of Foreign exports relative to Home goods and on the real exchange rate. The difference in relative prices when denominated in Home and Foreign currency is also reflected in the aggregate demand equation **(14)**.

Finally, under local currency pricing the real exchange rate and the terms of trade are not proportional (see **(16)-(20)**). In fact, a real exchange rate depreciation is likely to be associated with a terms of trade improvement as when prices are sticky in local currency, an exchange rate depreciation raises the home currency price of exports, but leaves import prices unchanged. Since in our framework a fraction of prices are free to adjust in each period, a real exchange rate depreciation could also be associated with a terms of trade deterioration. This becomes increasingly likely if we reduce the degree of price stickiness, but in the benchmark calibration we find that the terms of trade improve when the real exchange rate depreciates. The expenditure-switching effect of an exchange rate depreciation is therefore reduced relative to the model with producer currency pricing: there is no shift towards Home goods and relative prices of imported goods are not much affected (see also Betts and Devereux (2000)). A depreciation of the real exchange rate increases the revenues of Home exporters. Higher revenues also mean higher Home demand for Home goods (because Home wages also increase), leading to inflationary pressures in this sector.

$$\widehat{\pi}_{H,t} = k(\rho\widehat{C}_t + \eta\widehat{Y}_t + \lambda\widehat{T}_t + \widehat{\mu}_t) + \beta\widehat{\pi}_{H,t+1} \qquad \textbf{(11)}$$

$$\widehat{\pi}^*_{H,t} = k(\rho\widehat{C}_t + \eta\widehat{Y}_t - \widehat{RS}_t + \widehat{T}^*_t + \widehat{\mu}_t) + \beta\widehat{\pi}^*_{H,t+1} \qquad \textbf{(12)}$$

$$\widehat{\pi}_{F,t} = k(\rho\widehat{C}^*_t + \eta\widehat{Y}^*_t + \widehat{RS}_t - (1-\lambda)\widehat{T}_t + \widehat{\mu}_t) + \beta\widehat{\pi}_{F,t+1} \qquad \textbf{(13)}$$

$$\widehat{Y}_t = (1-\lambda)\widehat{C}_t + \lambda\widehat{C}^*_t + (1-\lambda)\theta\lambda\widehat{T}_t + \theta\lambda\widehat{T}^*_t \qquad \textbf{(14)}$$

$$\widehat{C}_t = \widehat{C}^*_t + \frac{1}{\rho}\widehat{RS}_t \tag{15}$$

$$\widehat{\pi}_t = (1-\lambda)\widehat{\pi}_{H,t} + \lambda\widehat{\pi}_{F,t} \tag{16}$$

$$\Delta\widehat{RS}_t = \Delta\widehat{S}_t + \widehat{\pi}^*_t - \widehat{\pi}_t \tag{17}$$

$$\widehat{T}_t - \widehat{T}_{t-1} = \widehat{\pi}_{F,t} - \widehat{\pi}_{H,t} \tag{18}$$

$$\widehat{T}^*_t - \widehat{T}^*_{t-1} = \widehat{\pi}^*_{F,t} - \widehat{\pi}^*_{H,t} \tag{19}$$

$$\Delta\widehat{ToT}_t = \widehat{\pi}_{F,t} - \Delta\widehat{S}_t - \widehat{\pi}^*_{H,t} \tag{20}$$

The Taylor curves under the assumption of local currency pricing and $\rho\theta > 1$ ($\rho = 2.5, \theta = 3$) are illustrated in Chart 3. As before, the blue line represents the case when $\delta^* = 0.05$ (Foreign central bank is hawkish) while the black line represents the case when $\delta^* = 5$ (Foreign central bank is dovish).

Chart 3: Home Taylor frontier under local currency pricing and $\rho\theta > 1$

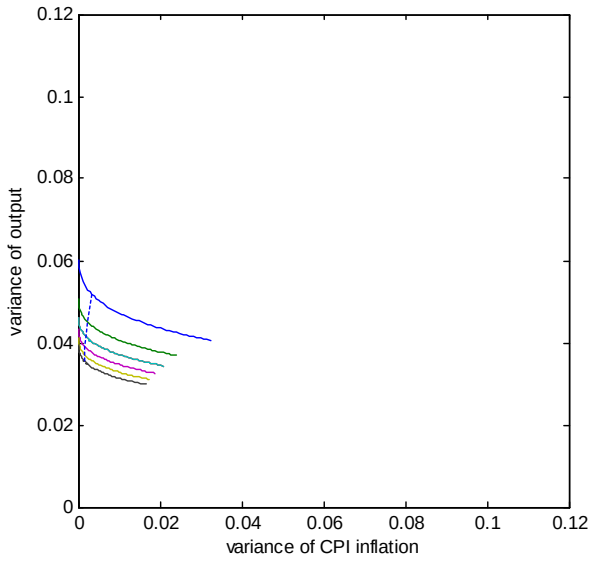


Chart 3 shows that the Taylor frontier facing Home now shifts inward as the Foreign central bank becomes more dovish, rather than outward, as in Case 1. Why is this? When the Foreign central bank tightens to counter the cost-push shock, the fall in Foreign wages and prices generates an improvement in the terms of trade for Home. The Foreign tightening also leads to a depreciation

of the Home nominal exchange rate. Since prices are sticky in local currencies, an exchange rate depreciation results in an increase in revenues for Home exporters and reduction in revenues for Foreign exporters. As a result, since only a fraction of exporters can adjust their destination market prices, we observe a reduction of Home export inflation and an increase in Home import inflation.

The rise in the Foreign exchange rate means that these Foreign currency revenues now buy a larger quantity of goods denominated in Home currency. This causes Home workers to feel wealthier, and so they want to work less. The resulting fall in labour supply pushes up on Home real wages and therefore on Home inflation. On the other hand, Foreign workers feel poorer as a result of the Foreign tightening, and Foreign demand for Home goods falls. So the two effects of a cost-push shock at Home – increased inflation and reduced output – are amplified. The more dovish the Foreign central bank, the weaker this amplifying effect, so that the Home central bank can achieve lower inflation and output volatility.

In sum: when products are priced in the local (consumer's) currency, the combinations of inflation and output variability achievable by the Home central bank improve as the Foreign central bank becomes more dovish: exactly the opposite to what we found for producer currency pricing. So like Betts and Devereux (2000) we find that under consumer currency pricing a Foreign monetary policy tightening is beggar-thy-neighbour. To give an estimate of the size of the effect: if we increase the Foreign central bank's weight on output stabilisation from 1 to 2, we reduce the variance of inflation by about 13% and the variance of output by 6% under the assumption that $\delta = 1$.

3.3.1 Shape of the Taylor curve under LCP and PCP

We also find that the Taylor curves facing the Home central bank are much flatter and squashed in the case of local currency pricing. Why is that? Under producer currency pricing, if the Home central bank tightens, the Home currency appreciates and the Home terms of trade improve. This makes Home workers feel richer, so they work less. This offsets some of the reduction in real wages and inflation achieved by Home's monetary tightening. Thus, a large reduction in output is needed to achieve a given reduction in inflation, making the Taylor curve under PCP relatively steep. Under local currency pricing, however, a tightening by the Home central bank worsens the

Home terms of trade: Home prices fall and so do import prices but not much as they are sticky in Home currency. The worsening terms of trade makes Home workers feel poorer, so they work harder. This further reduces real wages and inflation. So only a small fall in output is needed to generate a given reduction in inflation, making the Taylor curve under LCP relatively flat.

3.4 Sticky wages

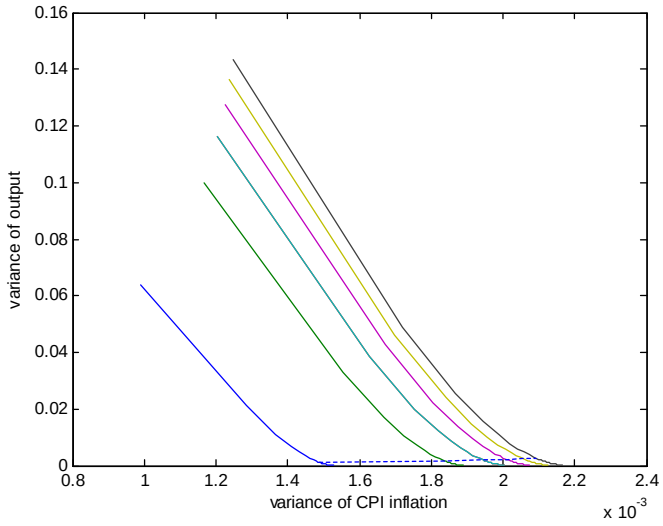
The effect of changes in the terms of trade on labour supply is an important channel of transmission between the two countries in the model. Since changes in labour supply are reflected in changes in real wages, this implies that the analysis is sensitive to the degree of wage flexibility. In the model, when the goods are substitutes in the utility, a deterioration in the terms of trade increases labour supply in Home as Home workers feel poorer and work harder. This shift in labour supply induces a fall in real wages, thus reducing inflation and increasing output. This is a key channel via which Foreign monetary policy – which affects Home's terms of trade – shifts the Home Taylor frontier.

We have experimented with a version of the model where monopolistically competitive households set nominal wages in staggered contracts as in Erceg, Henderson and Levin (2000). The introduction of wage stickiness does not alter the ranking of the Taylor curves. But as shown by Chart 4, sticky wages greatly reduces inflation volatility. Now the shift in labour supply induces a much smaller change in real wages and thus it attenuates its effect on inflation at Home. So nominal wage stickiness amplifies price stickiness by reducing the impact of the labour supply channel. When the Home central bank places equal weight on stabilising inflation and output ($\delta = 1$, represented by the dotted line), Home output volatility is also much more stable than under flexible wages for any value of δ^*. But if Home places only small weight on output stabilisation (as in Woodford (2003)'s closed economy, where $\delta = 0.05$), the variance of Home output is still strongly affected by the preferences of the Foreign central bank.

4 Discussion

The analysis clearly highlights two key factors in determining the impact on foreign monetary on a small open economy, namely the substitutability of goods produced in different countries, and the choice of invoicing currency. On the substitutability versus complementarity point the

Chart 4: Home Taylor frontier with sticky wages under local currency pricing and $\rho\theta > 1$



literature does offer some guidance on what would be reasonable parameter values. Obstfeld and Rogoff (2000a) survey various trade studies and find that goods are rather substitutes with elasticities in the neighbourhood of 5 to 6. Since the intertemporal elasticity of substitution is usually assumed to be less than 1, this would suggest that the goods are more likely to be substitutes in the utility.

On the specification of invoicing currency, arguments have been raised against both PCP and LCP. On the one hand, it has been observed that nominal depreciations tend to be followed by a terms of trade deterioration (price of exports falls relative to the price of imports). This would suggest that local currency pricing is counterfactual. On the other hand, producer currency pricing implies that nominal exchange rate changes should be passed through straight away into consumer prices. This too is counterfactual, as Devereux and Engel (2007) have pointed out: there is a substantial body of empirical evidence establishing that the link between movements in exchange rates and changes and national consumer prices is weak. As a way of addressing these observations, Devereux and Engel (2007) propose a model with high pass-through to import prices and weak pass-through to consumer goods prices.

Note that the invoicing currency matters in the preceding analysis because prices are assumed to be sticky in local currency. The assumption of price stickiness ensures that Home's terms of trade

shifts in the opposite directions under PCP and LCP in response to a Foreign monetary tightening. To illustrate this point, consider the case of LCP under the assumption of price flexibility. If prices are flexible, then the two scenarios of PCP and LCP are equivalent (see the appendix). When the Foreign central bank tightens monetary policy, the revenues of Home exporters increase and export prices of Home goods in Foreign currency decrease. This leads to a worsening of the terms of trade.

Our analysis is based on the assumption that asset markets are complete. Asset market completeness guarantees that the marginal rates of substitution in consumption are equalised between countries in all states and at all times in nominal terms (see Chari, Kehoe and McGrattan (2002)). This implies that there is a strong positive correlation between Home and Foreign consumption. Any improvement in Home's terms of trade will facilitate an increase in Home consumption and thus an increase in real wages. In a set-up with a lower degree of financial integration the countries would be less able to finance an increase in consumption by borrowing from abroad. Instead they would tend to keep their trade in balance by adjusting quantities produced.[5] As a result, the terms of trade would be more stable, and the effect of Foreign policy on the Home inflation-output trade-off would be reduced.

5 Conclusions

Monetary policy in a large Foreign economy affects the trade-off between inflation and output volatility faced by the central bank of Home, a small open economy. The impact of Foreign monetary policy on Home works through a demand channel as well as a supply channel. A key conclusion emerging from our analysis is that depending on the invoicing currency of exports and the degree of substitutability between Home and Foreign goods, a more 'dovish' central bank in the large economy could either improve or worsen the inflation-output trade-off faced by the small economy. Under PCP, the trade-off faced by the Home central bank is likely to worsen as the Foreign central bank becomes 'dovish' and more focused on output stabilisation rather than inflation stabilisation. However, the opposite is true under LCP.

We have analysed this issue using a model of sticky prices and flexible wages in an environment

[5] In the financial autarky case trade is always balanced, ie the value of Home consumption is always equal to the value of Home production.

of complete markets. We note that the terms of trade channel, which leads to shifts in Home labour supply and wages in response to Foreign monetary policy as well as to shifts in the demand for Home relative to Foreign goods, is the key driver of our results. A lower degree of financial market integration or the presence of sticky wages would reduce the importance of the terms of trade channel in affecting the trade-off faced by the Home central bank.

Appendix

Producer currency pricing (PCP) versus local currency pricing (LCP)

We allow for the possibility of price discrimination between the domestic and the foreign market. Under LCP firms in the traded good sector decide their prices maximising the expected profits subject to the demand schedule in a given market, ie the domestic or the foreign one:[6]

- domestic market

$$\max_{P_{H,t_0}(i)} E_{t_0} \sum_{t=t_0}^{\infty} (\alpha_H)^{t-t_0} Q_{t_0,t} \left[P_{H,t_0}(i) - \mu_{H,t} MC_t^H(i) \right] Y_{H,t_0:t}^d(i) \qquad \textbf{(A-1)}$$

$$subject\ to\ Y_{H,t_0:t}^d(i) = \left(\frac{P_{H,t_0}(i)}{P_{H,t}} \right)^{-\sigma} C_{H,t}; \qquad \textbf{(A-2)}$$

- foreign market

$$\max_{P_{H,t_0}^*(i)} E_t \sum_{t=t_0}^{\infty} (\alpha_H)^{t-t_0} Q_{t_0,t} \left[S_t P_{H,t_0}^*(i) - \mu_{H,t} MC_t^H(i) \right] Y_{H,t_0:t}^{*d}(i) \qquad \textbf{(A-3)}$$

$$subject\ to\ Y_{H,t_0:t}^{*d}(i) = \left(\frac{P_{H,t_0}^*(i)}{P_{H,t}^*} \right)^{-\sigma} Y_{H,t}^*. \qquad \textbf{(A-4)}$$

Where $Y_{H,t_0:t}^d(i)$, $Y_{H,t_0:t}^{*d}(i)$ – demands for the individual good produced by firm i at time t in the domestic and export home traded sector conditional on keeping, respectively, the prices $P_{H,t_0}(i)$ and $P_{H,t_0}^*(i)$ fixed at the level chosen at time t_0; MC_t^H – nominal marginal cost in the home traded sector at time t; and $\mu_{H,t}$ – markup shock in the home traded sector.

It follows that when prices are flexible, the optimal prices in the home traded sector (the internal price $\widetilde{P}_{H,t}$ and export price $\widetilde{P}_{H,t}^*$) are set at any time according to the following relations:

$$\frac{\widetilde{P}_{H,t}(i)}{P_t} = \mu_{H,t} MC_t^{H,r}(i) \frac{P_t}{P_{H,t}}, \qquad \textbf{(A-5)}$$

$$\frac{\widetilde{P}_{H,t}^*(i)}{P_t^*} = \mu_{H,t} MC_t^{H,r}(i) \frac{1}{RS_t} \frac{P_t^*}{P_{H,t}^*} = \mu_{H,t} MC_t^{H,r} \frac{P_t}{S_t P_{H,t}^*}, \qquad \textbf{(A-6)}$$

[6] We can separate pricing decisions depending on the market since our production function is linear.

where $MC_t^{H,r} = \frac{W_t^H(i)}{P_t A_t^H}$. Combining the two equations we get that:

$$\widetilde{P}_{H,t}(i) = S_t \widetilde{P}^*_{H,t}(i). \qquad \textbf{(A-7)}$$

This is equivalent to the PCP scenario.

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