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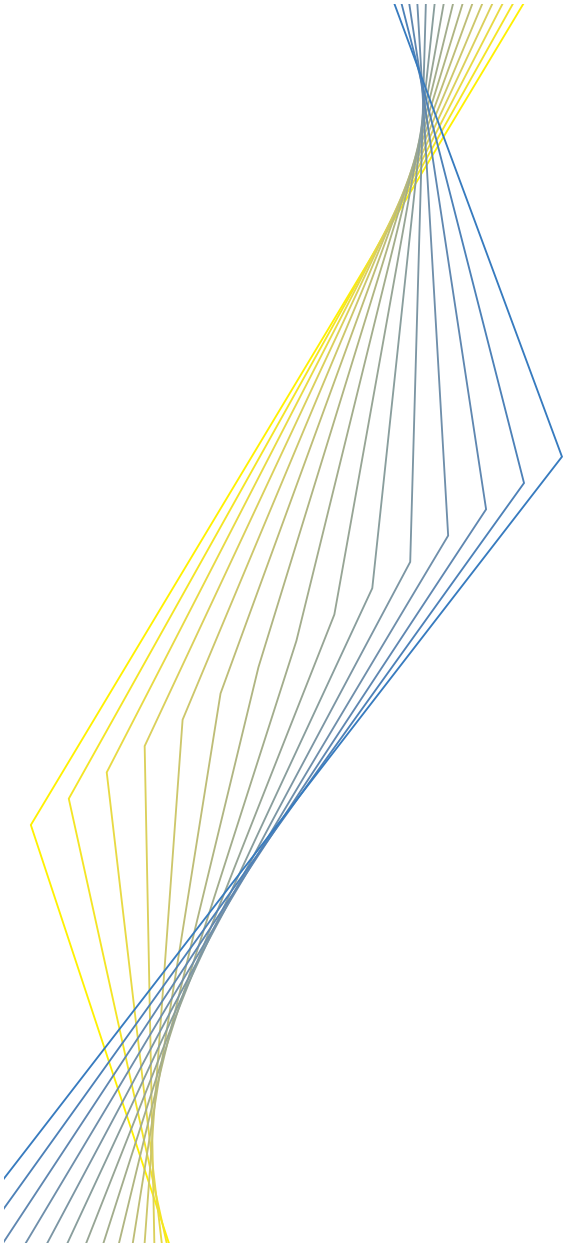

WORKING PAPER NO. 289

MONETARY AND FISCAL INTERACTIONS IN OPEN ECONOMIES[1]

BY GIOVANNI LOMBARDO[2] AND ALAN SUTHERLAND[3]

November 2003

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Contents

Abstract

A two-country sticky-price model is used to analyse the interactions between fiscal and monetary policy. The role of an 'activist' fiscal policy as a stabilisation tool is considered and a measure of the welfare gains from international fiscal policy cooperation is derived. It is found that welfare gains from fiscal cooperation do exist provided monetary policy is set cooperatively. There are also welfare gains from fiscal policy cooperation in a monetary union. However, it is found that a 'non-activist' fiscal policy can be better than non-cooperative fiscal policy when the international correlation of shocks is strongly negative. And non-cooperative fiscal policy can be better than cooperative fiscal policy if monetary policy is not set cooperatively. Keywords: Fiscal and monetary policy, policy coordination. JEL: E52, E58, F42

Non-Technical Summary

This paper analyses the interactions between fiscal and monetary policy when these policies are used as tools of macroeconomic stabilisation. There are two main questions of interest. First is the extent to which there is a role for fiscal policy as a stabilisation tool and the extent to which this interacts with monetary policy. Second is the scope for welfare gains from international fiscal policy cooperation and the interaction between these gains and the monetary policy regime. The formation of a monetary union in Europe and the debate about the Stability and Growth Pact make the analysis of fiscal and monetary interactions an especially interesting topic. It is often argued that the loss of monetary policy flexibility due to the merger of currencies increases the potential role of fiscal policy as a stabilisation tool and increases the need for fiscal policy cooperation within Europe. The issue of fiscal and monetary interaction also arises at the global level where concern about large fiscal and current account imbalances has added to the debate about policy coordination between the major world economies.

The appropriate role for monetary policy in a stochastic world has been a major topic of research in the last few years. Much attention has been focused on the welfare implications of monetary policy regimes, especially in cases where there is some degree of nominal rigidity. These welfare effects of monetary policy have also been an important topic in open economy research. In this context there has been extensive analysis of the role and scope for international monetary cooperation. The present paper is an attempt to build on this literature by incorporating a role for fiscal policy.

There is also an extensive existing literature which seeks to analyse the interaction between fiscal and monetary policy. One focus of the existing literature is the methodological parallels between the analysis of optimal monetary policy and optimal taxation. The question addressed is the extent to which monetary policy can be viewed as a distortionary policy instrument which can be used to offset other structural or stochastic distortions. In some respects this 'public finance' approach to monetary policy is beginning to tackle the interaction between monetary and fiscal policy as instruments of macroeconomic stabilisation. Although we do not adopt the methodology of this literature we are building on this work by considering monetary and fiscal interactions in a two-country world.

In order to investigate these issues we use a general equilibrium model with microeconomic foundations which allows us to measure the welfare effects of policy in terms of aggregate utility. We focus on a static (i.e. single period) version model with pre-set goods prices. This allows us to derive explicit analytical expressions for national welfare levels.

The analysis of fiscal policy begins with an analysis of a flexible-price version of the model. In this case monetary policy is neutral so it possible to study in isolation the implications of activist fiscal policy and the potential welfare gains from international fiscal policy cooperation. It is found that there is a role for activist fiscal policy and that there are welfare gains from cooperation. The welfare benefits of activist fiscal policy arise because supply-side shocks alter the natural level of output and thus require parallel movements in aggregate demand. The welfare gains to fiscal policy cooperation arise because the supply shocks in the two countries are not perfectly correlated so that national policymakers have conflicting objectives for world aggregate demand and the exchange rate. Indeed it is found that, when the cross-country correlation of shocks is sufficiently negative, the conflicting objectives of national policymakers can be so strong that non-activist fiscal policy may yield higher welfare than activist fiscal policy.

These issues are then reconsidered in a fixed-price version of the model. Firstly it is shown that optimal cooperative monetary policy (where national monetary authorities cooperate with each other) reproduces the flexible price equilibrium regardless of the fiscal policy regime. It therefore follows that the conclusions reached in the flexible-price case carry over to the fixed-price case provided monetary policy is set cooperatively. There are therefore welfare gains to activist fiscal policy and there are welfare gains to fiscal policy cooperation provided monetary authorities are cooperating.

The welfare gains from fiscal cooperation are, however, sensitive to the behaviour of monetary authorities. If national monetary authorities do not cooperate with each other it is found that fiscal policy cooperation can reduce welfare. There is thus a second-best quality to non-cooperative fiscal policy. The distortions created by non-cooperative fiscal policy partly offset the distortions created by non-cooperative monetary policy. It remains true, however, that monetary cooperation yields non-trivial welfare gains even when fiscal policy is not set cooperatively.

Finally we consider the role of fiscal policy in a monetary union. Monetary policy in a monetary union can not replicate the flexible price equilibrium but many of the results regarding fiscal policy continue to apply to the monetary-union case. It is again found that activist fiscal policy yields welfare gains and there are welfare gains to fiscal policy cooperation. But it is also true that non-activist fiscal policy can yield higher welfare than non-cooperative fiscal policy when the cross-country correlation of shocks is strongly negative.

1 Introduction

This paper uses a two-country model to analyse the interactions between fiscal and monetary policy when these policies are used as tools of macroeconomic stabilisation. There are two main questions of interest. First is the extent to which there is a role for fiscal policy as a stabilisation tool and the extent to which this interacts with monetary policy. Second is the scope for welfare gains from international fiscal policy cooperation and the interaction between these gains and the monetary policy regime. The formation of a monetary union in Europe and the debate about the 'Stability and Growth Pact' make the analysis of fiscal and monetary interactions an especially interesting topic. It is often argued that the loss of monetary policy flexibility due to the merger of currencies increases the potential role of fiscal policy as a stabilisation tool and increases the need for fiscal policy cooperation within Europe. The issue of fiscal and monetary interaction also arises at the global level where concern about large fiscal and current account imbalances has added to the debate about policy coordination between the major world economies.

The appropriate role for monetary policy in a stochastic world has been a major topic of research in the last few years. Much attention has been focused on the welfare implications of monetary policy regimes, especially in cases where there is some degree of nominal rigidity. These welfare effects of monetary policy have also been an important topic in open economy research. In this context there has been extensive analysis of the role and scope for international monetary cooperation. The present paper is an attempt to build on this literature by incorporating a role for fiscal policy.[1]

There is obviously also an extensive existing literature which seeks to analyse the interaction between fiscal and monetary policy (see Chari and Kehoe (1999)). One issue which has received considerable attention is the way in which the government's budget constraint creates links between fiscal and monetary policy.[2] This issue is not addressed in this paper. Another focus of the existing literature is the methodological parallels between the analysis of optimal monetary policy and optimal taxation. The question addressed in this literature is the extent to which monetary policy can be viewed as a distortionary policy instrument which can be used to offset other structural or stochastic distortions. Viewed in another way this

[1] For closed economy models see Woodford (2003) and the references cited therein. In the context of stochastic open-economy models, contributions to the modern theory of optimal monetary policy can be found in Obstfeld and Rogoff (1995, 1998, 2000, 2002), Corsetti and Pesenti (2001a,b), Devereux and Engel (2000), Benigno and Benigno (2001), Clarida et al. (2001) and Sutherland (2003). Canzoneri et al. (2002) highlight the contribution of the modern approach to international policy cooperation relative to the 'first generation' models. The latter are described in Canzoneri and Henderson (1991).

[2] This issue dates back at least to the 'Monetarist Arithmetic' of Sargent and Wallace (1981). Interest in this issues has re-emerged more recently thanks to contributions by Sims (1994), Woodford (2003, chapter 5) and Buiter (2002) on the fiscal theory of the price level.

'public finance' approach is beginning to tackle the interaction between monetary and fiscal policy as instruments of macroeconomic stabilisation (e.g. Correia et al. (2001)).

One possible way to tackle the questions analysed in the current paper would be to extend the 'public finance' approach to fiscal/monetary interactions to a two-country world and then to study the so-called 'Ramsey problem' from the perspective of individual national or world policymakers. However, we do not take this approach. Instead we adopt the methodology which has been used extensively in the recent open economic literature (e.g. Obstfeld and Rogoff (2002), Devereux and Engel (2000) and Corsetti and Pesenti (2001b)) . This involves deriving welfare functions (based on aggregate utility) which show the explicit dependence of welfare on policy instruments. It is then possible to use direct calculation to derive equilibria for a wide range of cooperative and non-cooperative regimes. In adopting this methodology we are following Beetsma and Jensen (2002) who analyse the interactions between fiscal and monetary policy in a monetary union using a microfounded model which incorporates fiscal policy in the form of government expenditure. They analyse optimal (cooperative) fiscal policy and compare the performance of a number of simple fiscal rules.

We use a version of the Beetsma and Jensen model which is simplified in some respects and extended in others. We focus on a static version of the model with pre-set prices. This allows us to derive explicit analytical expressions for national welfare levels. We extend the Beetsma and Jensen model by allowing the international elasticity of substitution between goods to differ from unity. This latter modification creates the possibility for gains from policy cooperation. The former modification makes it possible to analyse these gains explicitly. We use this framework to analyse the interaction between monetary and fiscal policy. In particular we analyse the role of activist fiscal policy and the scope for welfare gains from international fiscal policy cooperation.

The model is presented in Section 2 and the links between policy variables and welfare are discussed in Section 3. The analysis of fiscal policy begins in Section 4 where a flexible price version of the model is considered. In this case monetary policy is neutral so it possible to study in isolation the implications of activist fiscal policy and the potential welfare gains from fiscal policy cooperation. It is found that there is a role for activist fiscal policy and that there are welfare gains from cooperation. The welfare benefits of activist fiscal policy arise because labour supply shocks alter the natural level of output and thus require parallel movements in aggregate demand. The welfare gains to fiscal policy cooperation arise because imperfectly correlated labour supply shocks and movements in the terms of trade imply that national policymakers have conflicting objectives for world aggregate demand. Indeed it is found that, when the cross-country correlation of shocks is sufficiently negative, the conflicting objectives of Nash policymakers can be so strong that non-activist fiscal policy may yield higher welfare than activist fiscal policy.

Section 5 reconsiders these issues in a fixed-price version of the model. Firstly it is shown that optimal cooperative monetary policy reproduces the flexible price equilibrium regardless of the fiscal policy regime. It therefore follows that the conclusions reached in the flexible-price case carry over to the fixed-price case provided monetary policy is set cooperatively. There are therefore welfare gains to activist fiscal policy and there are welfare gains to fiscal policy cooperation provided monetary authorities are cooperating.

The welfare gains from fiscal cooperation are, however, sensitive to the behaviour of monetary authorities. If monetary authorities act as Nash players it is found that fiscal policy cooperation can reduce welfare. There is thus a second-best quality to non-cooperative fiscal policy. The distortions created by non-cooperative fiscal policy partly offset the distortions created by non-cooperative monetary policy. It remains true, however, that monetary cooperation yields non-trivial welfare gains even when fiscal policy is not set cooperatively.

Section 6 considers the role of fiscal policy in a monetary union. Monetary policy in a monetary union can not replicate the flexible price equilibrium but many of the results regarding fiscal policy continue to apply to the monetary-union case. It is again found that activist fiscal policy yields welfare gains and there are welfare gains to fiscal policy cooperation. But it is also true that non-activist fiscal policy can yield higher welfare than non-cooperative fiscal policy when the cross-country correlation of shocks is strongly negative.

Section 7 concludes the paper.

2 The Model

Market Structure

The world exists for a single period[3] 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 of goods containing 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 $f \in [0,1]$. All agents set prices in advance of the realisation of shocks and are contracted to meet demand at the pre-fixed prices.

[3] 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 (2001)). However, the approach adopted in this paper yields useful insights which would not be available in a more complex model.

Prices are set in the currency of the producer. 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.

Preferences

All agents in the home economy have utility functions of the same form. Utility depends positively on private consumption and real money balances and negatively on work effort. In addition agents receive utility from government consumption.[4] While the specific parameterisation of preferences might seem restrictive,[5] all the results discussed here are robust to more general CRRA preferences in consumption, real balances and government expenditure. The results concerning fiscal policy under flexible prices are also robust to a CRRA generalization of the preferences in labour. Nevertheless, the assumption of linear preferences in labour is necessary under fixed-prices for reasons of tractability.

The utility of agent h is given by

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

where C is a consumption index defined across all home and foreign goods, M denotes end-of-period nominal money holdings, P is the consumer price index, $y(h)$ is the output of good h, G is expenditure of the home fiscal authority, E is the expectations operator and K is a stochastic labour-supply shock (where $E[\log K] = 0$ and $Var[\log K] = \sigma^2 > 0$ and $\log K \in [-\epsilon, \epsilon]$).[6] The foreign economy is subject to labour-supply shocks (denoted K^*) of the same form as the home economy. χ and φ are positive constants. It is assumed that the variances of the shocks are identical across the two countries. The cross-country coefficient of correlation of shocks is given by υ where $-1 \leq \upsilon \leq 1$.

The consumption index C for home agents is defined as

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

[4] The assumption that government spending enters the utility function ensures that welfare maximising policymakers choose a positive level of government spending. However, it will become apparent that, within our model, the utility yielded by government consumption has no direct bearing on the use of fiscal policy as a stabilisation tool.

[5] Canzoneri et al. (2002) make the point that log-preferences eliminate important international spillovers in the standard 'New Open Economy' model.

[6] The assumption of a finite support for the probability distribution of the shocks makes it possible to adopt a simple and precise notation when presenting the solution of the model, but it involves no loss of generality. Notice that, by definition, σ must be less than or equal to ϵ.

where $\theta \geq 0$ is the elasticity of substitution between home and foreign goods. C_H and C_F are indices of home and foreign produced goods defined as follows

$$C_H = \left[\int_0^1 c_H(i)^{\frac{\phi-1}{\phi}} di\right]^{\frac{\phi}{\phi-1}}, \quad C_F = \left[\int_0^1 c_F(j)^{\frac{\phi-1}{\phi}} dj\right]^{\frac{\phi}{\phi-1}} \tag{3}$$

where $\phi > 1$ is the elasticity of substitution between domestically produced goods, $c_H(i)$ is consumption of home good i and $c_F(j)$ is consumption of foreign good j.

The budget constraint of agent h is given by

$$M(h) = M_0 + (1+\alpha)p_H(h)\,y(h) - PC(h) - T + PR(h) \tag{4}$$

where M_0 and $M(h)$ are initial and final money holdings, T is lump-sum government transfers or taxes, $p_H(h)$ is the price of home good h, P is the aggregate consumer price index and $R(h)$ is the income from a portfolio of state contingent assets (to be described in more detail below) and α is a production subsidy.[7]

Price Indices

The aggregate consumer price index for home agents is

$$P = \left[\frac{1}{2}P_H^{1-\theta} + \frac{1}{2}P_F^{1-\theta}\right]^{\frac{1}{1-\theta}} \tag{5}$$

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

$$P_H = \left[\int_0^1 p_H(i)^{1-\phi} di\right]^{\frac{1}{1-\phi}}, \quad P_F = \left[\int_0^1 p_F(j)^{1-\phi} dj\right]^{\frac{1}{1-\phi}} \tag{6}$$

The law of one price is assumed to hold. This implies $p_H(i) = p_H^*(i)\,S$ and $p_F(j) = p_F^*(j)\,S$ 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). Purchasing power parity holds in terms of aggregate consumer price indices, $P = P^*S$. The real terms of trade is given by $\tau = P_H/(SP_F^*)$.

Consumption Choices

Individual home demand for representative home good, h, and foreign good, f, are given by

$$c_H(h) = C_H\left(\frac{p_H(h)}{P_H}\right)^{-\phi}, \quad c_F(f) = C_F\left(\frac{p_F(f)}{P_F}\right)^{-\phi} \tag{7}$$

[7] The production subsidy is introduced as a modelling device which makes it possible to set the 'baseline' or average level of output of the two economies. We set the subsidy so that the distortions created by monopoly are completely offset and average output is at its first-best level.

where

$$C_H = \frac{1}{2} C \left(\frac{P_H}{P} \right)^{-\theta}, \quad C_F = \frac{1}{2} C \left(\frac{P_F}{P} \right)^{-\theta} \tag{8}$$

Foreign demands for home and foreign goods have an identical structure to the home demands. Individual foreign demand for representative home good, h, and foreign good, f, are given by

$$c_H^*(h) = C_H^* \left(\frac{p_H^*(h)}{P_H^*} \right)^{-\phi}, \quad c_F^*(f) = C_F^* \left(\frac{p_F^*(f)}{P_F^*} \right)^{-\phi} \tag{9}$$

where

$$C_H^* = \frac{1}{2} C^* \left(\frac{P_H^*}{P^*} \right)^{-\theta}, \quad C_F^* = \frac{1}{2} C^* \left(\frac{P_F^*}{P^*} \right)^{-\theta} \tag{10}$$

Fiscal Policy

The fiscal policy instrument is assumed to be the level of government spending. Government spending in each country takes the form of a basket of home and foreign goods with a structure identical to that of private consumption.[8]

The fiscal authority in each country chooses a rule for the setting of government spending. These rules may depend on the realisations of the supply shocks in each country and take the form

$$G = \bar{G} K^{\delta_{G,K}} K^{*\delta_{G,K^*}} \text{ and } G^* = \bar{G}^* K^{\delta^*_{G,K}} K^{*\delta^*_{G,K^*}} \tag{11}$$

The feedback coefficients, δ_{GK}, δ_{GK^*}, δ^*_{GK} and $\delta^*_{GK^*}$, are assumed to be chosen by policymakers before goods prices are set and shocks are realised and policymakers are assumed to be able to commit to their choice of rule.[9]

[8] Note that the structure of the consumers' basket implies that there is no home bias in consumption. Our assumption that fiscal expenditures have the same structure as private consumption expenditure therefore implies that there also is no home bias in fiscal expenditure. In this respect we depart from Beetsma and Jensen (2003), who assume complete home base in fiscal expenditure (i.e. the home fiscal authority purchases only home goods and the foreign fiscal authority purchases only foreign goods). As pointed out by Campbell Leith in his discussion of our paper, our assumption somewhat limits the usefulness of fiscal policy as a stabilising tool in the face of imperfectly correlated national shocks. We acknowledge that our structure is an extreme case in this respect. However, the opposite assumption (of complete home bias) is also an extreme case. A more reasonable structure would lie somewhere between the two extremes. In all essential qualitative respects the results we report below also hold in a model with partial home bias in fiscal expenditures.

[9] In general there is no reason to suppose that fully optimal fiscal policy will fall within the class of log-linear feedback rules specified here. However, given that our analysis is based on a linear-quadratic approximation of the model and the welfare function, it is the case that, within the approximated model, fully optimal policy can be represented by log-linear feedback rules. The same observations apply to the log-linear feedback rules for monetary policy (which are described below).

The form of the fiscal rules show that the fiscal policymaking problem can be divided into two separate sets of decisions. One set of decisions relates to the determination of the average levels of G and G^*. In terms of (11) this amounts to the determination of $\bar{G}$ and $\bar{G}^*$. The other set of decisions relates to the determination of the feedback parameters, δ_{GK}, δ_{GK^*}, δ^*_{GK} and $\delta^*_{GK^*}$. Clearly both these sets of decisions are of interest and can be analysed using the current model. The main focus of this paper is, however, on the use of fiscal policy as a stabilisation tool. For this reason the analysis focuses on the determination of the feedback parameters, while $\bar{G}$ and $\bar{G}^*$ are treated as fixed and exogenous. The share of government spending in total output in a non-stochastic equilibrium is denoted γ (i.e. $\gamma = \bar{G}/\bar{Y}$ where $\bar{Y}$ is the level of aggregate home output in a non-stochastic equilibrium). Thus, given our assumption that the levels of $\bar{G}$ and $\bar{G}^*$ are fixed, γ is treated as a fixed exogenous parameter.[10] The model is symmetric across the two countries, so $\gamma = \bar{G}^*/\bar{Y}^*$.

Aggregate Output

Combining the expressions for private consumption and government expenditure implies that aggregate home and foreign output levels are

$$Y = Y_W \left(\frac{P_H}{P}\right)^{-\theta}, \quad Y^* = Y_W \left(\frac{P^*_F}{P^*}\right)^{-\theta} \tag{12}$$

where

$$Y_W = \frac{1}{2}\left(C + C^* + G + G^*\right)$$

Money Demand and Supply

The first-order condition for the choice of money holdings is

$$\frac{M}{P} = \chi C \tag{13}$$

[10] An alternative approach would be explicitly to derive welfare maximising values of $\bar{G}$ and $\bar{G}^*$ for a non-stochastic equilibrium. The resulting values of $\bar{G}$ and $\bar{G}^*$ would be positive (provided government spending yields utility) and increasing functions of φ (i.e. the weight given to government spending in utility). The implied value of γ would thus also be a positive and increasing function of φ. The equilibrium values of $\bar{G}$ and $\bar{G}^*$ (and thus the value of γ) would also depend on the international regime governing the choice of $\bar{G}$ and $\bar{G}^*$ (i.e. whether or not there is international co-operation over the choice of $\bar{G}$ and $\bar{G}^*$). In the analysis presented in this paper it is implicitly assumed that international regime governing the choice fiscal feedback parameters is independent from the regime governing the choice of $\bar{G}$ and $\bar{G}^*$. Thus γ is assumed to have the same value in both cooperative and non-cooperative regimes for the choice of δ_{GK}, δ_{GK^*}, δ^*_{GK} and $\delta^*_{GK^*}$. We believe that this is a realistic assumption because the debate about fiscal policy cooperation usually relates to the use of fiscal policy as a stabilisation tool - it does not extend to consideration of international cooperation over the absolute size of the public sector.

The monetary policy instrument is assumed to be the money supply.[11] The monetary authority in each country chooses a rule for the setting of the money supply. These rules may depend on the realisations of the supply shocks in each country and take the form

$$M = M_0 K^{\delta_{MK}} K^{*\delta_{MK^*}} \text{ and } M^* = M_0^* K^{\delta^*_{MK}} K^{*\delta^*_{MK^*}} \tag{14}$$

As in the case of fiscal policy, the feedback parameters δ_{MK}, δ_{MK^*}, δ^*_{MK} and $\delta^*_{MK^*}$ are chosen by policymakers before prices are set and shocks are realised, and it is assumed that policymakers are able to commit to their choice of rule.[12]

The Government Budget Constraint

The budget constraint of the home fiscal authority is

$$M - M_0 - \alpha P_H Y + T - PG = 0 \tag{15}$$

where G is real total home government purchases and Y is the aggregate output of the home economy. The level of lump-sum transfers is treated as a residual element which is assumed to adjust to ensure that the government budget constraint is satisfied in all states of the world.

Financial Markets and Risk Sharing

It is assumed that sufficient contingent financial instruments exist to allow efficient sharing of consumption risks. The only source of consumption risk faced by consumers is variability in real disposable income so efficient sharing of consumption risk can be achieved by allowing trade in two state-contingent assets, one which has a payoff correlated with home real disposable income and one with a payoff correlated with foreign real disposable income. For simplicity it is assumed that each asset pays a return equal to the relevant country's real disposable income, i.e. a unit of the home asset pays $y_d = y - G$ and a unit of the foreign asset pays $y^*_d = y^* - G^*$ where $y = YP_H/P$ and $y^* = Y^*P_F/P$. The portfolio payoffs for home and foreign agents are given by the following

$$R(h) = \zeta_H(h)(y_d - q_H) + \zeta_F(h)(y^*_d - q_F) \tag{16}$$

$$R^*(f) = \zeta^*_H(f)(y_d - q_H) + \zeta^*_F(f)(y^*_d - q_F) \tag{17}$$

[11] Lombardo and Sutherland (2003) show that in this type of model the choice of monetary instrument (money supply v. interest rate) can have small quantitative effects on welfare. This fact holds true also in the present paper. Nevertheless none of the results presented here depends, qualitatively, on the instrument of monetary policy.

[12] Notice that anticipated monetary policy is completely neutral in terms of real variables so (in contrast to fiscal policy) the analysis of monetary policy is only meaningful in terms of the feedback parameters δ_{MK}, δ_{MK^*}, δ^*_{MK} and $\delta^*_{MK^*}$.

where $\zeta_H(h)$ and $\zeta_F(h)$ are holdings of home agent h of the home and foreign assets, $\zeta_H^*(f)$ and $\zeta_F^*(f)$ are the holdings of foreign agent f of home and foreign assets and q_H and q_F are the unit prices of the home and foreign assets. It is shown in the Appendix that asset market equilibrium implies the following relationship between consumption levels, asset prices and expectations of real disposable income in the two countries

$$\frac{C}{C^*} = \frac{q_H}{q_F} = \frac{E\left[\frac{y_d}{y_d+y_d^*}\right]}{E\left[\frac{y_d^*}{y_d+y_d^*}\right]} \tag{18}$$

Thus relative consumption levels depend on the ratio of expected shares of national income in world disposable income.

It is assumed that asset markets open *after* policymakers have made their choice of monetary and fiscal policy rules. This implies that agents can insure themselves against the risk implied by a particular set of policy rules but they can not insure themselves against all possible policy rules. This is important when considering the non-cooperative choice of policy rules because it implies that national policymakers internalise the impact of their choice of policy rule on their country's share of world real disposable income. To see this more clearly consider the implications of equation (18). If, for instance, the home policymaker adopts a policy rule which depresses the expected share of home income in world disposable income then (other things being equal) q_H/q_F must be less than unity, and thus foreign consumption must be higher than home consumption. This shift of consumption towards the foreign economy is a welfare cost to home agents which tends to discourage home policymakers from adopting policy rules which depress home disposable income.[13]

It is shown in the Appendix that a second-order expansion of (18) around a non-stochastic equilibrium implies the following[14]

$$\hat{C} - \hat{C}^* = E\left[\frac{(\hat{y}-\hat{y}^*) - \gamma\left(\hat{G}-\hat{G}^*\right)}{1-\gamma} - \frac{\gamma\left[\left(\hat{y}-\hat{G}\right)^2 - \left(\hat{y}^*-\hat{G}^*\right)^2\right]}{2(1-\gamma)^2}\right] + O\left(\epsilon^3\right) \tag{19}$$

where the term $O(\epsilon^3)$ denotes all terms of third order and higher in deviations from the non-stochastic equilibrium.[15] This expression shows clearly that relative

[13] This welfare cost would not be internalised by Nash policymakers if asset trade takes place before policy rules are chosen. Sutherland (2003) shows that the welfare losses implied by non-cooperative monetary policymaking are much higher in this case. Consideration of this alternative structure raises some technical and theoretical issues which are difficult to deal with in the current model. We therefore focus on the case where asset trade takes place after policy rules are chosen.

[14] The non-stochastic equilibrium of the model is defined to be the solution which results when $K = K^* = 1$ with $\sigma^2 = 0$. For any variable X define $\hat{X} = \log\left(X/\bar{X}\right)$ where $\bar{X}$ is the value of variable X in the non-stochastic equilibrium.

[15] The remainder term in a second-order expansion of any equation is at most of order $O(\epsilon^3)$

consumption levels are determined by expected relative output levels and expected relative levels of government spending. It is also apparent that relative consumption levels are affected by the relative volatility of disposable income in the two countries. An increase in $E[(\hat{y} - \hat{G})^2]$ tends to decrease home consumption relative to foreign consumption and vice versa for an increase in $E[(\hat{y}^* - \hat{G}^*)^2]$.[16]

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 (net of the production subsidy α) is given by $\Phi = \phi/\left[(\phi - 1)(1 + \alpha)\right]$. The first-order condition for price setting implies the following

$$P_H = \Phi \frac{E\left[KY\right]}{E\left[Y/(PC)\right]} \tag{20}$$

Notice that the price level contains a form of risk premium which will depend on the variances and covariances of the variables on the right hand side of (20). This can be seen more clearly by considering a second-order approximation of (20)

$$\hat{P}_H = E\left[\hat{K} + \hat{P} + \hat{C}\right] + \lambda_{P_H} + O\left(\epsilon^3\right) \tag{21}$$

where

$$\lambda_{P_H} = \frac{1}{2} E\left[\hat{K}^2 + 2\hat{K}\hat{Y} - \hat{P}^2 - \hat{C}^2 + \hat{Y}\hat{P} + \hat{Y}\hat{C} - \hat{P}\hat{C}\right]$$

where λ_{P_H} is the risk premium. Similar expressions can be derived for foreign producer prices, P_F^*. The foreign risk premium is denoted $\lambda_{P_F^*}$.

3 Welfare

Following Obstfeld and Rogoff (1998, 2002) it is assumed that the utility of real balances is small enough to be neglected. The aggregate welfare of home agents is therefore measured by the following

$$\Omega = E\left[\log C - KY + \varphi \log G\right] \tag{22}$$

It is not possible to derive an exact expression for welfare (except in special cases). The model is therefore solved as a second-order approximation around a non-stochastic equilibrium. This allows a second-order accurate solution for welfare to be derived.

because the log deviations of all the endogenous variables of the model are proportional to the log deviations of the supply shocks and the supply shocks are of maximum absolute size ϵ.

[16] These second-order terms arise because of the convexity of y_d and y_d^* in $\hat{y}$, $\hat{G}$, $\hat{y}^*$ and $\hat{G}^*$.

Second-Order Approximation of Welfare

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

$$\tilde{\Omega} = E\left\{\hat{C} - \bar{Y}\left[\hat{Y} + \frac{1}{2}\left(\hat{Y} + \hat{K}\right)^2\right]\right\} + O\left(\epsilon^3\right) \tag{23}$$

where $\tilde{\Omega}$ is the deviation in the level of welfare from the non-stochastic equilibrium.[17] The model solution procedure described in the Appendix allows the home and foreign welfare expressions to be rewritten entirely in terms of second moments as follows

$$\tilde{\Omega} = \frac{1}{4(1-\gamma)}E\left[-\Delta - \frac{\theta}{2}\hat{\tau}^2 - 4\hat{Y}_W\hat{K} + 2\theta\hat{\tau}\hat{K} + 2\theta\hat{\tau}\hat{Y}_W + \frac{2(1-\gamma)}{\theta-\gamma}\left(\lambda_{P_H} - \lambda_{P_F^*}\right) - \Psi\right] + t.i.p. + O\left(\epsilon^3\right) \tag{24}$$

and

$$\tilde{\Omega}^* = \frac{1}{4(1-\gamma)}E\left[-\Delta - \frac{\theta}{2}\hat{\tau}^2 - 4\hat{Y}_W\hat{K}^* - 2\theta\hat{\tau}\hat{K}^* - 2\theta\hat{\tau}\hat{Y}_W - \frac{2(1-\gamma)}{\theta-\gamma}\left(\lambda_{P_H} - \lambda_{P_F^*}\right) + \Psi\right] + t.i.p. + O\left(\epsilon^3\right) \tag{25}$$

where $t.i.p.$ indicates 'terms independent of policy' and

$$\Delta = (1-\gamma)\hat{C}^2 + (1-\gamma)\hat{C}^{*2} + \gamma\hat{G}^2 + \gamma\hat{G}^{*2} \tag{26}$$

$$\Psi = \frac{\gamma(1-\gamma+\theta)}{(1-\gamma)(\theta-\gamma)}\left[\left(\hat{y} - \hat{G}\right)^2 - \left(\hat{y}^* - \hat{G}^*\right)^2\right] \tag{27}$$

In deriving these expressions the production subsidy, α, is set so that the level of output in the non-stochastic equilibrium is at its optimal level. This implies that $\bar{Y} = 1/(1-\gamma)$.[18]

These expressions show that welfare depends in a relatively complex way on the second moments of output, consumption, the terms of trade and policy variables.

[17] Notice that the term representing the utility of government spending does not appear in (23). This is because the expected log-deviation of government spending (from the non-stochastic equilibrium) is zero. The parameter φ therefore does not appear in (23) and thus it has no direct role in the optimal choice of the feedback parameters in the fiscal rules. In a more general analysis of fiscal policy, where the fiscal authorities are also allowed optimally to determine $\bar{G}$ and $\bar{G}^*$, the parameter φ would indeed become relevant, and the equilibrium values of $\bar{G}$ and $\bar{G}^*$ would be positive and increasing functions of φ. But this is not the issue we are addressing in this paper.

[18] This assumption is adopted because it represents a convenient benchmark. It has no qualitative effect on the results presented below.

The welfare expressions can be made easier to interpret by decomposing national welfare levels as follows

$$\tilde{\Omega} = \tilde{\Omega}_W + \tilde{\Omega}_R, \quad \tilde{\Omega}^* = \tilde{\Omega}_W - \tilde{\Omega}_R \tag{28}$$

where $\tilde{\Omega}_W \equiv (\tilde{\Omega}+\tilde{\Omega}^*)/2$ is world aggregate welfare, and $\tilde{\Omega}_R \equiv (\tilde{\Omega}-\tilde{\Omega}^*)/2$ is 'relative' welfare. Using these definitions it is simple to show that

$$\begin{aligned}\tilde{\Omega}_W = \frac{1}{4(1-\gamma)} E \Big[& -\Delta - \frac{\theta}{2}\hat{\tau}^2 \\ & -2\hat{Y}_W \left(\hat{K} + \hat{K}^*\right) + \theta\hat{\tau}\left(\hat{K} - \hat{K}^*\right)\Big] + t.i.p. + O\left(\epsilon^3\right)\end{aligned} \tag{29}$$

and

$$\begin{aligned}\tilde{\Omega}_R = \frac{1}{4(1-\gamma)} E \Big[& -2\hat{Y}_W \left(\hat{K} - \hat{K}^*\right) + \theta\hat{\tau}\left(\hat{K} + \hat{K}^*\right) + 2\theta\hat{\tau}\hat{Y}_W \\ & + \frac{2(1-\gamma)}{\theta-\gamma}\left(\lambda_{P_H} - \lambda_{P_F^*}\right) - \Psi\Big] + t.i.p. + O\left(\epsilon^3\right)\end{aligned} \tag{30}$$

By definition cooperative policymakers maximise $\tilde{\Omega}_W$ while non-cooperative policy care about both $\tilde{\Omega}_W$ and $\tilde{\Omega}_R$. It is therefore possible to understand the cooperative policymaking by considering $\tilde{\Omega}_W$ and to understand the differences between cooperative and non-cooperative equilibria by considering the impact of policy on $\tilde{\Omega}_R$.

To interpret the welfare expressions it is also useful to consider the links between monetary and fiscal policy and output. (Note that second-order accurate solutions to second moments can be obtained from first-order accurate solutions to the variables of the model so the following discussion is based on a log-linearised version of the model.) A first-order approximation for (12) shows that output in each country is given by

$$\hat{Y} = \hat{Y}_W - \frac{\theta}{2}\hat{\tau} + O\left(\epsilon^2\right), \quad \hat{Y}^* = \hat{Y}_W + \frac{\theta}{2}\hat{\tau} + O\left(\epsilon^2\right) \tag{31}$$

where

$$\hat{Y}_W = \frac{(1-\gamma)}{2}\hat{C} + \frac{(1-\gamma)}{2}\hat{C}^* + \frac{\gamma}{2}\hat{G} + \frac{\gamma}{2}\hat{G}^* + O\left(\epsilon^2\right) \tag{32}$$

Notice that national output levels depend on world aggregate demand and the terms of trade. World demand affects the two countries symmetrically while the terms of trade gives rise to an 'expenditure switching effect'. An improvement in the home terms of trade causes a switch of demand from home goods to foreign goods. This effect is stronger the larger is the elasticity of substitution between home and foreign goods (i.e. the larger is θ). Further insight into the way policy variables affect output (and therefore welfare) can be gained by considering the first-order solutions for the terms of trade and consumption levels. It is simple to show (using the price setting

equations, the risk sharing condition and the money market equations) that the terms of trade are given by

$$\hat{\tau} = -\hat{S} = \hat{M}^* - \hat{M} + O\left(\epsilon^2\right) \tag{33}$$

and consumption levels are given by

$$\hat{C} = \hat{C}^* = \frac{\hat{M} + \hat{M}^*}{2} + O\left(\epsilon^2\right) \tag{34}$$

These expressions reveal an important contrast between the way fiscal and monetary policy variables affect output. Fiscal policy variables only affect national output levels through their effect on world demand, so fiscal policy affects home and foreign output symmetrically. But monetary policy variables affect both world demand (through their effect on consumption) and the terms of trade, so monetary policy can have an asymmetric effect on home and foreign output.

Welfare, Policy and Policy Interactions

By considering the expressions for home and foreign output, consumption and the terms of trade it is possible to gain some understanding of the links between policy variables and welfare. It is also possible to see the elements in the welfare expressions which generate interactions between fiscal and monetary policymakers within and across the two countries.

First consider the expression for $\tilde{\Omega}_W$ given in (29). It is clear that the first two terms in this expression are the variances of the components of aggregate demand. An increase in the variance of any component of aggregate demand (other things being equal) increases the variance of output in both countries and reduces world welfare. The third term in (29) is the covariance between the aggregate world supply shock $(\hat{K} + \hat{K}^*)$ and aggregate demand, $\hat{Y}_W$. A positive value of $(\hat{K} + \hat{K}^*)$ indicates that, in aggregate (across the world), agents would prefer to reduce work effort, so world welfare improves when there is negative covariance between $(\hat{K}+\hat{K}^*)$ and $\hat{Y}_W$. The forth term in (29) is the covariance between the terms of trade and the relative supply shock, $(\hat{K} - \hat{K}^*)$. When, for instance, $(\hat{K} - \hat{K}^*)$ is positive home agents would like to reduce labour supply more than foreign agents. World welfare would therefore be improved by a shift in aggregate demand from home goods to foreign goods. This can be achieved by an improvement in the home terms of trade. Thus world welfare is increasing in the covariance between $(\hat{K} - \hat{K}^*)$ and $\hat{\tau}$.

Notice that none of the terms in $\tilde{\Omega}_W$ generates any interactions between fiscal and monetary policy. It is simple to see that the choice of fiscal policy rules which maximises $\tilde{\Omega}_W$ is independent of the behaviour of monetary policy. And the choice of monetary policy rules which maximises $\tilde{\Omega}_W$ is independent of the behaviour of fiscal policy.

Now consider the expression for $\tilde{\Omega}_R$ given in (30). All the terms in this expression highlight factors which affect home and foreign welfare in opposite directions. Thus the first term shows that a positive correlation between $\hat{Y}_W$ and $(\hat{K} - \hat{K}^*)$ reduces home welfare but increases foreign welfare (because home agents would like output to fall when $\hat{K}$ rises and foreign agents would like output to rise when $\hat{K}^*$ falls). The second term shows that a positive correlation between $(\hat{K} + \hat{K}^*)$ and the terms of trade increases home welfare but reduces foreign welfare (because, when $\hat{K}$ rises, home agents would like $\hat{\tau}$ to rise in order to reduce home output and, when $\hat{K}^*$ rises, foreign agents would like $\hat{\tau}$ to fall in order to reduce foreign output). The third term shows that a positive correlation between $\hat{Y}_W$ and the terms of trade increases home welfare but reduces foreign welfare (because, when $\hat{Y}_W$ rises, home agents would like $\hat{\tau}$ to rise in order to reduce home output and foreign agents would like $\hat{\tau}$ to fall in order to reduce foreign output).

The fourth term in $\tilde{\Omega}_R$ depends on the risk premia which are built into pre-set goods prices. An increase in the home risk premium relative to the foreign risk premium reduces home work effort and increases foreign work effort. This has a positive effect on home welfare and a negative effect on foreign welfare. The fifth term in $\tilde{\Omega}_R$ arises because of the effects of disposable income volatility on the risk sharing relationship. As explained above (in relation to equation (19)) an increase in the variance of $\hat{y} - \hat{G}$ relative to the variance of $\hat{y}^* - \hat{G}^*$ reduces the expected level of home consumption relative to the expected level of foreign consumption. This has a negative effect on home welfare and a positive effect on foreign welfare.

It is clear that all five of the terms in $\tilde{\Omega}_R$ give rise to a potential divergence between cooperative and non-cooperative policymaking. It is also apparent that the third, fourth and fifth terms in $\tilde{\Omega}_R$ give rise to potential interactions between fiscal and monetary policymakers. Each of these terms is jointly determined by the behaviour of fiscal and monetary authorities in both countries so the optimal behaviour of any one policymaker (when behaving as a Nash player) will potentially depend on the behaviour of the other three policymakers.

4 Flexible Prices

Before considering the potential interaction between fiscal and monetary policy regimes it is useful to gain some understanding of the role of fiscal policy by considering a flexible price version of the model. If goods prices are perfectly flexible (so that they are set after shocks are realised and policy variables are determined) then monetary policy becomes completely neutral with respect to real variables. In this case it is simple to show that consumption levels are given by

$$\hat{C} = \hat{C}^* = -\frac{\hat{K} + \hat{K}^*}{2} + O\left(\epsilon^2\right) \tag{35}$$

and the terms of trade are given by

$$\hat{\tau} = \hat{K} - \hat{K}^* + O\left(\epsilon^2\right) \tag{36}$$

Furthermore the risk premia in prices are zero

$$\lambda_{P_H} = \lambda_{P_F^*} = 0$$

Fiscal policy variables, however, continue to be non-neutral, both in terms of their effects on output and welfare.[19] It is therefore possible to use the flexible price case to gain some understanding of the role of activist fiscal policy and to analyse the scope for welfare gains from fiscal policy cooperation.

Using the world welfare expression (29) it is possible to show that fiscal cooperation results in the following optimal feedback coefficients in the fiscal rules

$$\delta_{G,K} = \delta^*_{G,K^*} = \delta_{G,K^*} = \delta^*_{G,K} = -\frac{1}{2} \tag{37}$$

and the level of world welfare yielded by cooperative fiscal policy is

$$\tilde{\Omega}_C^{flex} = \frac{(1-\upsilon)(\theta-1)}{4\,(1-\gamma)}\,\sigma^2 \tag{38}$$

The optimal feedback coefficients in (37) show that cooperative fiscal policy implies that government spending in both countries reacts negatively to the supply shocks. To understand this consider the example of a positive shock to K. An increase in K implies that home agents would like to reduce labour supply. Notice from equation (35) that the flexible-price equilibrium ensures that private consumption in both countries automatically falls in order to accommodate this desire for lower home-country work effort. But private consumption is only one component of aggregate demand - the other component is government spending. In order to ensure that total aggregate demand (i.e. private consumption plus government spending) contracts in response to the shock it is necessary for fiscal authorities to cut government spending. This decision is embodied in the choice of feedback coefficients. Notice

[19] Government spending is a real variable which alters the equilibrium level of real output even when prices are fully flexible. An increase in government spending causes an increase in aggregate demand which (given the infinite elasticity of labour supply) causes a matching increase in aggregate supply. If the elasticity of labour supply was less than infinite then government spending would cause some crowding out of private consumption. But this crowding out would be less that complete as long as labour supply is not totally inelastic. Fiscal policy will always affect welfare (regardless of the degree of price stickiness and the elasticity of labour supply) because government spending alters the balance between private consumption and work effort (and also because government spending directly enters the utility function).

that the optimal fiscal feedback coefficients in (37) imply government spending reacts to shocks in exactly the same way as private consumption reacts to shocks.[20]

The cooperative outcome can be compared to a non-cooperative equilibrium where national fiscal authorities act as Nash players. A Nash equilibrium in the choice of fiscal policy rules yields the following policy coefficients

$$\begin{array}{c} \delta_{G,K} = \delta^*_{G,K^*} = \frac{2(1-\gamma)+(3\,\theta-2)}{-4(1-\gamma)+2\,(1-2\,\theta)} \\ \delta_{G,K^*} = \delta^*_{G,K} = \frac{2(1-\gamma)+\theta}{-4(1-\gamma)+2(1-2\,\theta)} \end{array} \tag{39}$$

And the Nash equilibrium level of world welfare is

$$\tilde{\Omega}^{flex}_N = \frac{(\theta-1)\,(1-3\,\gamma+4\,\gamma^2+4\,\theta-9\gamma\,\theta+4\,\theta^2)\,(1-\upsilon)}{4\,(1-\gamma)\,(1-2\gamma+2\,\theta)^2}\,\sigma^2 \tag{40}$$

The difference between the cooperative and Nash welfare outcomes is given by the following expression

$$\tilde{\Omega}^{flex}_C - \tilde{\Omega}^{flex}_N = \frac{\gamma\,(\theta-1)^2\,(1-\upsilon)}{4\,(1-\gamma)\,(1-2\gamma+2\,\theta)^2}\,\sigma^2 \tag{41}$$

The following propositions can now be stated:

Proposition 1 *Under flexible prices there are welfare gains from fiscal cooperation* iff

1) The share of steady-state government spending in output is positive ($\gamma > 0$),

2) The demand for imported goods relative to domestically produced goods is not unit-elastic ($\theta \neq 1$).

3) The supply shocks are not perfectly positively correlated ($\upsilon \neq 1$).

The proof of this proposition follows easily from inspection of equation (41).

To understand the existence of welfare gains from fiscal policy cooperation it is useful to consider the decomposition of welfare presented in equations (28), (29) and (30). Cooperative policy by definition maximises $\tilde{\Omega}_W$, whereas Nash policymakers are attempting to maximise $\tilde{\Omega}$ and $\tilde{\Omega}^*$. It therefore follows that the difference between Nash policy and cooperative policy can be understood by considering the impact of policy on $\tilde{\Omega}_R$. Notice that fiscal policy enters $\tilde{\Omega}_R$ only through its impact on $\hat{Y}_W$ and Ψ. It is immediately clear that these terms create a policy conflict between home

[20] The need for an activist fiscal policy can be understood at a more basic level by considering the utility function. Private consumption and government spending enter the utility function in an identical form. It is obvious that welfare maximising fiscal policy in a flexible price world should make government spending behave in the same way as private consumption.

and foreign fiscal policymakers. The home policymaker would like to use fiscal policy to create a negative correlation between $\hat{Y}_W$ and $\hat{K} - \hat{K}^*$ and a positive correlation between $\hat{Y}_W$ and $\hat{\tau}$.[21] But the foreign policymaker would like these correlations to have the opposite signs. A similar conflict is created by the Ψ term (defined in (27)). The home policymaker would like to use fiscal policy to reduce the variance of $(\hat{y} - \hat{G})$ and increase the variance of $(\hat{y}^* - \hat{G}^*)$ in order to shift relative asset prices in the favour of home agents. The foreign policymaker would like to achieve the opposite shift in relative asset prices by increasing the variance of $(\hat{y} - \hat{G})$ and reducing the variance of $(\hat{y}^* - \hat{G}^*)$. Each of these policy conflicts creates an incentive for Nash policymakers to deviate from the cooperative policy rule and thus creates potential welfare gains from fiscal policy cooperation.[22]

In order to give some idea of the magnitude of the welfare gains from fiscal cooperation Table 1 reports some numerical values for $\tilde{\Omega}_C^{flex} - \tilde{\Omega}_N^{flex}$ for ranges of values of γ and θ. These values represent percentages of consumption in the non-stochastic equilibrium. It is clear that the welfare gains, though positive, are not large for empirically plausible parameter values.[23]

The cooperative and Nash outcomes can also be compared to the equilibrium implied by a non-activist fiscal policy (i.e. a policy where all the fiscal feedback parameters are set to zero). Non-activist fiscal policy yields the following level of world welfare

$$\tilde{\Omega}_P^{flex} = \frac{(1+\upsilon)(1-\gamma) + (1-\upsilon)\theta - 2}{4(1-\gamma)}\sigma^2 \tag{42}$$

where the subscript 'P' indicates a 'passive' or 'non-activist' policy. The difference between the cooperative and the non-activist welfare outcomes is

$$\tilde{\Omega}_C^{flex} - \tilde{\Omega}_P^{flex} = \frac{\gamma(1+\upsilon)}{4(1-\gamma)}\sigma^2 \tag{43}$$

The following proposition can now be stated:

Proposition 2 *Under flexible prices the cooperative solution is superior to the non-activist solution* iff

1) The share of steady-state government spending in output is positive ($\gamma > 0$),

[21] The former correlation ensures that home output falls when home agents experience a negative labour supply shock. The latter correlation ensures that movements in world demand offset the impact of terms of trade shocks on home output.

[22] Notice that the policy conflicts disappear (and thus the cooperative and Nash equilibria are identical) when the supply shocks are perfectly positively correlated or when $\theta = 1$.

[23] The standard deviation of the shocks, σ, is set at 1/10 and the cross-country correlation of shocks is set at zero. The lowest value of θ considered is 4/5. For $\gamma = 2/5$ and for values of θ lower than 4/5 some of the second-order conditions of the national policy optimisation problems do not hold so no valid Nash equilibria exist.

2) The supply shocks are not perfectly negatively correlated ($\upsilon \neq -1$).

The proof of this proposition follows easily from inspection of equation (43).

From the definition of $\tilde{\Omega}_W$ in equation (29) it is simple to see that cooperative fiscal policy will coincide with the non-activist policy when shocks are perfectly negatively correlated. When $\upsilon = -1$ it follows that $\hat{K} + \hat{K}^* = 0$ (i.e. there is no aggregate uncertainty). But, because fiscal policy can only affect aggregate world demand, cooperative fiscal policy can only generate a welfare benefit (relative to an non-activist policy) by creating a negative correlation between world demand and the world aggregate shock. By definition this benefit is zero when there is no aggregate world shock.

Propositions (1) and (2) imply the following corollary:

Corollary 1 *If $\theta \neq 1$ and $\gamma \neq 0$, then for a sufficiently negative correlation between the supply shocks the Nash-solution is inferior to the non-activist solution.*

Proof. Under the conditions stated in the corollary, the cooperative solution is always superior to the Nash equilibrium. The distance between the two solutions (in terms of welfare) *decreases* monotonically in υ while the distance between the cooperative solution and the non-activist outcome *increases* monotonically in υ. Hence there must be a value for υ (different from -1) such that the two distances cross. ■

As explained above, when shocks are strongly negatively correlated the volatility of $(\hat{K} + \hat{K}^*)$ is low, so cooperative policy offers very little welfare gain compared to non-activist policy. But a strong negative correlation of shocks also implies that the volatility of $(\hat{K} - \hat{K}^*)$ (and therefore $\hat{\tau}$) is very high. This creates a strong incentive for Nash policymakers to deviate from the cooperative solution. For a sufficiently negative correlation of shocks this incentive can be so strong that the Nash equilibrium yields lower welfare than the non-activist equilibrium.

5 Sticky Prices

We now turn to the case where prices are set in advance of the realization of the shocks. This implies that both fiscal and monetary policy are non-neutral. It is now possible to re-examine the role of activist fiscal policy and the scope for welfare gains from fiscal policy cooperation in the presence of activist monetary policy. It is also possible to examine the role of activist monetary policy and the scope for welfare gains from monetary policy cooperation in the presence of activist fiscal policy.

5.1 Does Monetary Cooperation Imply Fiscal Policy is Redundant?

When the two fiscal authorities and the two monetary authorities all cooperate and choose the policy rules in order to maximise world welfare, $\tilde{\Omega}_W$, the following welfare level is achieved

$$\tilde{\Omega}_{MCFC} = \frac{(\upsilon - 1)(1 - \theta)}{4\,(1 - \gamma)}\,\sigma^2. \tag{44}$$

(where the subscript $MCFC$ denotes 'monetary cooperation and fiscal cooperation') We can then state the following proposition

Proposition 3 *Cooperation under predetermined prices and under flexible prices produces the same level of welfare.*

The proof simply follows from the comparison of equations (38) and (44).

Now consider the case where only the two monetary authorities cooperate, while the fiscal authorities choose their actions as Nash players. The difference in welfare level between this case and the full cooperation case is

$$\tilde{\Omega}_{MCFC} - \tilde{\Omega}_{MCFN} = \frac{\gamma\,(\theta - 1)^2\,(1 - \upsilon)}{4\,(1 - \gamma)\,(1 - 2\gamma + 2\,\theta)^2}\,\sigma^2. \tag{45}$$

(where the subscript $MCFN$ denotes 'monetary cooperation, fiscal Nash'). This expression shows that total cooperation is never inferior to the case where only the monetary authorities cooperate.

Finally if the fiscal authorities adopt a non-activist stance (i.e. the feedback parameters in the fiscal rules are set to zero) while the monetary authorities cooperate, the welfare level yielded is exactly as in equation (42). Since equation (45) is also identical to equation (41), together with proposition 3 the following statement is proved.

Proposition 4 *Under predetermined prices cooperation among monetary authorities produces the flexible price allocation regardless of the fiscal regime.*

An alternative way to verify this result is to note that the cooperative choice of monetary rules implies the following choice of monetary policy feedback parameters

$$\begin{aligned} \delta_{M,K} &= \delta^*_{M,K^*} = -1 \\ \delta_{M,K^*} &= \delta^*_{M,K} = 0 \end{aligned} \tag{46}$$

It is simple to see from the expression for $\tilde{\Omega}_W$ given in (29) that this choice of feedback parameters is independent of the behaviour of fiscal policymakers. It immediately follows from (33) and (34) that the monetary feedback parameters in (46)

reproduce the flexible-price behaviour of consumption and the terms of trade given in (35) and (36). It also follows that $\lambda_{P_H} = \lambda_{P_F^*} = 0$. Thus the statement in Proposition 4 is confirmed. In intuitive terms this can be understood more easily by noting that, in the flexible-price world, private agents choose consumption optimally to respond to shocks (whether in the form of supply shocks or fiscal policy shocks). These private consumption decisions will also be socially optimal (provided monopoly distortions are completely offset by a production subsidy). It therefore follows that, in the sticky-price world, cooperative monetary policy (which, by definition, aims to achieve the social optimum) will reproduce the flexible-price equilibrium.[24]

So, if monetary policy alone can reproduce the flexible price allocation, is there a role for fiscal policy? The answer to this question is implicit in propositions 2, 3 and 4, and can be summarized in the following corollary

Corollary 2 *Under predetermined prices, if the monetary authorities cooperate, there is a positive stabilization role for government expenditure if points* 1) *and* 2) *of proposition 2 hold true. A Nash solution to the fiscal policy problem can go some way to fulfil this role only if the fundamental shocks are not too negatively correlated.*

In other words, since under monetary cooperation the role of fiscal policy under predetermined prices is identical to that played under flexible prices, activist fiscal policy will improve welfare in those cases in which it does so under flexible prices.

It follows from these results that the welfare effects of fiscal cooperation reported in Table 1 for the flexible-price case are also relevant for the sticky-price case. It thus also follows that the welfare gains of fiscal cooperation appear not to be large for empirically plausible parameter values even when prices are sticky.

5.2 Does Fiscal Cooperation Imply Monetary Policy is Redundant?

The above results demonstrate that monetary policy cooperation can reproduce the flexible price equilibrium regardless of the fiscal policy equilibrium. It is interesting also to consider whether fiscal policy cooperation can reproduce the flexible price equilibrium without the help of monetary policy. If the central banks follow a non-activist policy (i.e. all the feedback parameters in the monetary rules are set to zero) it is found that fiscal cooperation results in the same fiscal rules as under flexible prices (see equations (37)). The welfare yielded in this scenario is

[24] It should be noted that the results summarised in Propositions 3 and 4 do not necessarily hold in the case where monopoly distortions are not fully offset with a production subsidy. In this case the equilibrium generated by cooperative monetary policy may differ from the flexible-price equilibrium because the cooperative monetary policy maker will attempt to move the expected level of output towards the first-best level by, for instance, reducing output volatility so that producers are encouraged to increase work effort.

$$\tilde{\Omega}_{MPFC} = \frac{(\gamma(1+\upsilon)-2)}{4\ (1-\gamma)}\,\sigma^2 \tag{47}$$

(where $MPFN$ denotes 'monetary non-activist, fiscal Nash'). Comparison of equation (47) with equation (38) proves the following proposition

Proposition 5 *Fiscal cooperation by itself does not reproduce the flexible price allocation.*

An alternative way to verify this result is to note from (35) and (36) that the flexible-price equilibrium requires private consumption and the terms of trade to respond to the supply shocks. But (33) and (34) show that, in a sticky-price equilibrium only monetary policy has the power to induce the required movements in private consumption and the terms of trade.

In the context of our model, it has just been shown that fiscal policy does not bring about the flexible price equilibrium. But does monetary policy improve on the allocation that simple fiscal cooperation can achieve? The answer is given by the difference between equation (44) and (47), that is

$$\tilde{\Omega}_{MCFC} - \tilde{\Omega}_{MPFC} = \frac{((1-\gamma)\ (1+\upsilon)+\theta\,(1-\upsilon))}{4\ (1-\gamma)}\,\sigma^2 \tag{48}$$

Since this expression is always positive, the following proposition is proved

Proposition 6 *Under predetermined prices and non-distortionary taxes, fiscal policy alone does not produce the same allocation that it would produce in the presence of an activist optimal monetary policy.*

5.3 Cooperating Over Only One Instrument

The above results have analysed the implications of fiscal policy against the background of cooperative monetary policy and the implications of monetary policy against the background of cooperative fiscal policy. But does fiscal policy cooperation still yield gains when monetary authorities are behaving as Nash players and does monetary policy cooperation yield welfare gains when fiscal authorities are behaving as Nash players?

First consider the welfare effects of fiscal policy cooperation against the background of non-cooperative monetary policy. When monetary policy is not set cooperatively the welfare gain yielded by fiscal policy cooperation is

$$\tilde{\Omega}_{MNFC} - \tilde{\Omega}_{MNFN} = \frac{(1-\upsilon)(1-\theta)^2\left[2-3\gamma^2+5\theta-6\theta^2+\gamma^2(8+3\theta)+\gamma(\theta^2-4\theta-7)\right]}{4(1-\gamma)(1+\gamma-2\theta)^2\theta(1-2\gamma+2\theta)^2}\,\sigma^2 \tag{49}$$

(where $MNFC$ denotes 'monetary Nash, fiscal cooperation' and $MNFN$ denotes 'monetary Nash, fiscal Nash'). This expression can be negative or positive. The implications can be summarised in the following proposition.

Proposition 7 *When monetary authorities act as Nash players the welfare difference between cooperative fiscal policy and Nash equilibrium fiscal policy will be positive if* $\underline{\theta} < \theta < \bar{\theta}$*, negative if* $\theta > \bar{\theta}$ *or* $\theta < \underline{\theta}$ *and zero if* $\theta = \bar{\theta}$ *or* $\theta = \underline{\theta}$ *where*

$$\begin{aligned} \underline{\theta} &= \frac{-5+4\gamma-3\gamma^2+\sqrt{73-216\gamma+266\gamma^2-128\gamma^3+21\gamma^4}}{2(\gamma-6)} \\ \bar{\theta} &= \frac{-5+4\gamma-3\gamma^2-\sqrt{73-216\gamma+266\gamma^2-128\gamma^3+21\gamma^4}}{2(\gamma-6)}. \end{aligned}$$

Numerical calculation shows that $\underline{\theta}$ is close to zero while $\bar{\theta}$ is close to unity for empirically relevant values of γ. Fiscal cooperation can therefore have a negative welfare effect for empirically plausible values of γ and θ. Table 2 reports some numerical values for $\tilde{\Omega}_{MNFC} - \tilde{\Omega}_{MNFN}$. It is again evident that the welfare effects of fiscal cooperation, whether positive or negative, are not large.

Now consider the welfare effect of monetary policy cooperation against the background of Nash fiscal policy. The welfare gain yielded by monetary cooperation when fiscal authorities act as Nash players is given by the expression

$$\tilde{\Omega}_{MCFN} - \tilde{\Omega}_{MNFN} = \frac{(1-\upsilon)(1-\theta)^2\left[1+\gamma^2+\gamma(\theta-2)+\theta(1-2\theta)\right]^2}{4(1-\gamma)(1+\gamma-2\theta)^2\theta(1-2\gamma+2\theta)^2}\,\sigma^2 \qquad (50)$$

(where $MCFN$ denotes 'monetary cooperation, fiscal Nash'). It is clear that this is expression is always positive. This leads to the following proposition

Proposition 8 *There are gains from monetary policy cooperation even when fiscal authorities act as Nash players.*

Table 3 reports some numerical calculations for the welfare gains from monetary cooperation. The table shows the effects of monetary cooperation both with fiscal cooperation (i.e. $\tilde{\Omega}_{MCFC} - \tilde{\Omega}_{MNFC}$) and without fiscal cooperation (i.e. $\tilde{\Omega}_{MCFN} - \tilde{\Omega}_{MNFN}$). It is evident that the welfare effects of monetary cooperation can be much larger that the welfare effects of fiscal cooperation. It is also evident that the welfare effects of monetary cooperation are relatively unaffected by the presence or absence of fiscal cooperation.

6 Monetary Union

In this section we consider the case of a monetary union. In a monetary union the two countries are subject to the same unique monetary policy, hence $\delta_{M,K} = \delta^*_{M,K^*}$ and $\delta_{M,K^*} = \delta^*_{M,K}$. Clearly therefore the question of monetary policy cooperation no longer arises. However, fiscal authorities retain independent policy instruments so it remains relevant to consider the role of activist fiscal policy and to analyse the scope for welfare gains from fiscal policy cooperation.

The welfare level yielded by fiscal cooperation in a monetary union (where the common monetary policy is chosen to maximise world welfare) is

$$\tilde{\Omega}_{MUFC} = \frac{(\upsilon - 1)}{4(1-\gamma)}\,\sigma^2 \tag{51}$$

(where $MUFC$ denotes 'monetary union, fiscal cooperation'). A comparison between this expression and (44) shows that, when shocks are less than perfectly correlated, a monetary union with optimal monetary policy combined with cooperative fiscal policy can not achieve the welfare level delivered by separate currencies and full fiscal and monetary policy cooperation. It also follows that a monetary union can not replicate the flexible price equilibrium (unless shocks are perfectly correlated).

The welfare level yielded by Nash equilibrium fiscal policy in a monetary union is

$$\tilde{\Omega}_{MUFN} = \frac{(\upsilon - 1)\left[4\gamma^2 + (1+2\theta)^2 - \gamma(3 + 10\theta - \theta^2)\right]}{4(1-\gamma)(1-2\gamma+2\theta)^2}\,\sigma^2 \tag{52}$$

(where $MUFN$ denotes 'monetary union, fiscal Nash'). And the welfare yielded by passive fiscal policy in a monetary union is

$$\tilde{\Omega}_{MUFP} = \frac{(\upsilon - 1) - (1+\upsilon)\gamma}{4(1-\gamma)}\,\sigma^2 \tag{53}$$

(where $MUFP$ denotes 'monetary union, fiscal passive').

The welfare gain from fiscal policy cooperation is therefore given by

$$\tilde{\Omega}_{MUFC} - \tilde{\Omega}_{MUFN} = \frac{(1-\upsilon)\gamma(1-\theta)^2}{4(1-\gamma)(1-2\gamma+2\theta)^2}\,\sigma^2 \tag{54}$$

And the welfare gain for cooperative fiscal policy relative to non-activist fiscal policy is

$$\tilde{\Omega}_{MUFC} - \tilde{\Omega}_{MUFP} = \frac{(1+\upsilon)\gamma}{4(1-\gamma)}\,\sigma^2 \tag{55}$$

It is easy to see from these expressions that the results summarised in Propositions 1 and 2 and Corollary 1 for the flexible price case also hold in the monetary union case. In other words, in a monetary union an activist fiscal policy will improve welfare in those cases in which it does so in the flexible price and monetary cooperation cases.

7 Conclusion

This paper has analysed the interaction between fiscal and monetary policy in a two-country sticky-price model. It is found that a world policymaker seeking to maximise world aggregate utility would use both fiscal and monetary policy as tools

of stabilisation policy. There is therefore a stabilisation role for fiscal policy in addition to monetary policy. It is also found that, in general, a regime of full policy cooperation yields higher welfare than non-cooperative policy (where either fiscal or monetary policy is set at a national level by policymakers who act as Nash players). There are therefore welfare gains to both monetary and fiscal policy cooperation.

It does not follow, however, that in all circumstances cooperative fiscal policy is better than non-cooperative fiscal policy. For instance, it is found that, when monetary authorities act as Nash players, a Nash equilibrium in fiscal policy yields higher welfare than cooperative fiscal policy. It also does not follow that activist fiscal policy is better than non-activist fiscal policy. It is generally found that, regardless of the monetary policy regime, non-activist fiscal policy yields higher welfare than activist fiscal policy if fiscal authorities act as Nash players and the cross country correlation of shocks is strongly negative.

Appendix

Portfolio allocation and asset prices

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

$$E\left[C^{-1}y_d\right] = E\left[C^{-1}\right]q_H, \quad E\left[C^{-1}y_d^*\right] = E\left[C^{-1}\right]q_F \tag{56}$$

$$E\left[C^{*-1}y_d\right] = E\left[C^{*-1}\right]q_H, \quad E\left[C^{*-1}y_d^*\right] = E\left[C^{*-1}\right]q_F \tag{57}$$

The combination of the private and government budget constraints and the portfolio payoff functions for each country imply that aggregate home and foreign consumption levels are given by

$$C = y_d + \zeta_H\left(y_d - q_H\right) + \zeta_F\left(y_d^* - q_F\right) \tag{58}$$

$$C^* = y_d^* + \zeta_H^*\left(y_d - q_H\right) + \zeta_F^*\left(y_d^* - q_F\right) \tag{59}$$

where in a symmetric equilibrium $\zeta_H(h) = \zeta_H$ and $\zeta_F(h) = \zeta_F$ for all h and $\zeta_H^*(f) = \zeta_H^*$ and $\zeta_F^*(f) = \zeta_F^*$ for all f. Equilibrium in asset markets implies $\zeta_H + \zeta_H^* = 0$ and $\zeta_F + \zeta_F^* = 0$. These equations can be used to solve for q_H, q_F, ζ_H, ζ_F, ζ_H^*, ζ_F^*, C and C^* in terms of y_d and y_d^*.

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

$$q_H = \frac{E\left[\frac{y_d}{y_d+y_d^*}\right]}{E\left[\frac{1}{y_d+y_d^*}\right]}, \quad q_F = \frac{E\left[\frac{y_d^*}{y_d+y_d^*}\right]}{E\left[\frac{1}{y_d+y_d^*}\right]} \tag{60}$$

Consumption levels in the two countries are given by

$$C = \frac{q_H\left(y_d + y_d^*\right)}{q_H + q_F}, \quad C^* = \frac{q_F\left(y_d + y_d^*\right)}{q_H + q_F} \tag{61}$$

and the portfolio shares are given by

$$\zeta_H = -\zeta_H^* = -\frac{q_F}{q_H + q_F}, \quad \zeta_F = -\zeta_F^* = \frac{q_H}{q_H + q_F} \tag{62}$$

Notice that (61) implies

$$\frac{C}{C^*} = \frac{q_H}{q_F} \tag{63}$$

Second-order approximations of the asset price equations (60) yield

$$\hat{q}_H = E\left[\hat{y}_d - \frac{1}{2}\hat{y}_d\hat{y}_d^*\right] + O\left(\epsilon^3\right), \quad \hat{q}_F = E\left[\hat{y}_d^* - \frac{1}{2}\hat{y}_d\hat{y}_d^*\right] + O\left(\epsilon^3\right) \tag{64}$$

so home and foreign consumption are related as follows

$$\hat{C} - \hat{C}^* = E\left[\hat{y}_d - \hat{y}_d^*\right] + O\left(\epsilon^3\right) \tag{65}$$

It is useful to note that second-order approximations of y_d and y_d^* are given by

$$\hat{y}_d = \frac{1}{1-\gamma}\hat{y} - \frac{\gamma}{1-\gamma}\hat{G} + \lambda_{y_d} + O\left(\epsilon^3\right), \quad \hat{y}_d^* = \frac{1}{1-\gamma}\hat{y}^* - \frac{\gamma}{1-\gamma}\hat{G}^* + \lambda_{y_d^*} + O\left(\epsilon^3\right)$$

where

$$\lambda_{y_d} = -\frac{\gamma}{2(1-\gamma)^2}\left(\hat{y} - \hat{G}\right)^2, \quad \lambda_{y_d^*} = -\frac{\gamma}{2(1-\gamma)^2}\left(\hat{y}^* - \hat{G}^*\right)^2$$

thus

$$\hat{C} - \hat{C}^* = E\left[\frac{\left(\hat{y} - \hat{y}^*\right) - \gamma\left(\hat{G} - \hat{G}^*\right)}{1-\gamma} - \frac{\gamma\left[\left(\hat{y} - \hat{G}\right)^2 - \left(\hat{y}^* - \hat{G}^*\right)^2\right]}{2(1-\gamma)^2}\right] + O\left(\epsilon^3\right) \tag{66}$$

Model solution

The model is made up of the set of equations in (67) (which is derived as a second-order approximation of the structural equations).

$$\left.\begin{array}{l}
\hat{P}_H = E\left[\hat{C}\right] + E\left[\hat{P}\right] + \lambda_{P_H} + O\left(\epsilon^3\right) \\
\hat{P}_F^* = E\left[\hat{C}^*\right] + E\left[\hat{P}^*\right] + \lambda_{P_F^*} + O\left(\epsilon^3\right) \\
\hat{Y} = \hat{Y}_W + \theta\hat{P} - \theta\hat{P}_H \\
\hat{Y}^* = \hat{Y}_W + \theta\hat{P}^* - \theta\hat{P}_F^* \\
\hat{Y}_W = \frac{(1-\gamma)}{2}\hat{C} + \frac{(1-\gamma)}{2}\hat{C}^* + \frac{\gamma}{2}\hat{G} + \frac{\gamma}{2}\hat{G}^* + \lambda_{Y_W} + O\left(\epsilon^3\right) \\
\hat{C} = \hat{M} - \hat{P} \\
\hat{C}^* = \hat{M}^* - \hat{P}^* \\
\hat{P} = \frac{\hat{P}_H}{2} + \frac{\hat{P}_F^* + \hat{S}}{2} + \lambda_P + O\left(\epsilon^3\right) \\
\hat{P}^* = \frac{\hat{P}_H - \hat{S}}{2} + \frac{\hat{P}_F^*}{2} + \lambda_P + O\left(\epsilon^3\right) \\
\hat{y}_d = \frac{1}{1-\gamma}\left(\hat{P}_H - \hat{P} + \hat{Y}\right) - \frac{\gamma}{1-\gamma}\hat{G} + \lambda_{y_d} + O\left(\epsilon^3\right) \\
\hat{y}_d^* = \frac{1}{1-\gamma}\left(\hat{P}_F^* - \hat{P}^* + \hat{Y}^*\right) - \frac{\gamma}{1-\gamma}\hat{G}^* + \lambda_{y_d^*} + O\left(\epsilon^3\right) \\
\hat{C} = \hat{C}^* + E\left[\hat{y}_d\right] - E\left[\hat{y}_d^*\right] + O\left(\epsilon^3\right) \\
\hat{G} = \delta_{GK}\hat{K} + \delta_{GK^*}\hat{K}^* \\
\hat{G}^* = \delta_{GK}^*\hat{K} + \delta_{GK^*}^*\hat{K}^* \\
\hat{M} = \delta_{MK}\hat{K} + \delta_{MK^*}\hat{K}^* \\
\hat{M}^* = \delta_{MK}^*\hat{K} + \delta_{MK^*}^*\hat{K}^* \\
\tilde{\Omega} = E\left[\hat{C}\right] - \frac{1}{1-\gamma}E\left[\hat{Y}\right] - \frac{1}{1-\gamma}\lambda_\Omega + O\left(\epsilon^3\right) \\
\tilde{\Omega}^* = E\left[\hat{C}^*\right] - \frac{1}{1-\gamma}E\left[\hat{Y}^*\right] - \frac{1}{1-\gamma}\lambda_{\Omega^*} + O\left(\epsilon^3\right)
\end{array}\right\} \tag{67}$$

The second-order terms are collected below in (68).

$$\Lambda \equiv \begin{bmatrix} \lambda_{P_H} \\ \lambda_{P_F^*} \\ \lambda_{Y_W} \\ \lambda_P \\ \lambda_{y_d} \\ \lambda_{y_d^*} \\ \lambda_\Omega \\ \lambda_{\Omega^*} \end{bmatrix} = \begin{bmatrix} \frac{1}{2}E\left[\left(\hat{K}+\hat{Y}\right)^2 - \left(\hat{C}+\hat{P}-\hat{Y}\right)^2\right] \\ \frac{1}{2}E\left[\left(\hat{K}^*+\hat{Y}^*\right)^2 - \left(\hat{C}^*+\hat{P}^*-\hat{Y}^*\right)^2\right] \\ \frac{1}{2}\left[\frac{(1-\gamma)}{2}\hat{C}^2 + \frac{(1-\gamma)}{2}\hat{C}^{2*} + \frac{\gamma}{2}\hat{G}^2 + \frac{\gamma}{2}\hat{G}^{2*} - \hat{Y}_W^2\right] \\ \frac{(1-\theta)}{8}\left(\hat{P}_F^* - \hat{P}_H + \hat{S}\right)^2 \\ -\frac{\gamma}{2(1-\gamma)^2}\left[\left(\hat{P}_H - \hat{P} + \hat{Y}\right) - \hat{G}\right]^2 \\ -\frac{\gamma}{2(1-\gamma)^2}\left[\left(\hat{P}_F^* - \hat{P}^* + \hat{Y}^*\right) - \hat{G}^*\right]^2 \\ \frac{1}{2}E\left[\left(\hat{K}+\hat{Y}\right)^2\right] \\ \frac{1}{2}E\left[\left(\hat{K}^*+\hat{Y}^*\right)^2\right] \end{bmatrix} \tag{68}$$

The system is solved for the following vector of endogenous variables

$$V' = \begin{bmatrix} \hat{P}_H & \hat{P}_F^* & \hat{Y} & \hat{Y}^* & \hat{Y}_W & \hat{C} & \hat{C}^* & \hat{P} & \hat{P}^* & \hat{y}_d & \hat{y}_d^* & \hat{S} & \hat{G} & \hat{G}^* & \hat{M} & \hat{M}^* & \tilde{\Omega} & \tilde{\Omega}^* \end{bmatrix}$$

In order to describe the solution method it is convenient to write the model in matrix form as follows

$$A_1 V = A_2 E[V] + A_3 \Lambda + A_4 \xi + O\left(\epsilon^3\right) \tag{69}$$

where $\xi' = \begin{bmatrix} \hat{K} & \hat{K}^* \end{bmatrix}$ and A_1, A_2, A_3 and A_4 are matrices of coefficients taken from equation system (67).

Notice that, to obtain a solution for welfare, it is sufficient to solve for $E[V]$. The solution method follows Sutherland (2002) and can be thought of as consisting of two steps. In the first step expectations are taken of both sides of (69) and the resulting matrix equation is solved for $E[V]$ in terms of $E[\Lambda]$. This yields

$$E[V] = (A_1 - A_2)^{-1} A_3 E[\Lambda] + O\left(\epsilon^3\right) \tag{70}$$

(Note that $E[\xi] = 0$ by assumption.) The two final elements of $E[V]$ in (70) yield expressions for home and foreign welfare in terms of the second-order terms contained in $E[\Lambda]$. After some further rearrangement it is possible to derive the welfare expressions given in the main text in equations (24) and (25).

The welfare expressions given in (24) and (25) are not full reduced forms in the sense that some of the variables on the right-hand side are endogenous. Full reduced-form welfare expressions can be obtained by moving to the second step of the solution process. In this step a first-order approximation of the model is used to obtain a second-order accurate solution for $E[\Lambda]$ in terms of the exogenous variables

and parameters of the model (i.e. in terms of the policy feedback coefficients and the parameters describing the stochastic properties of the shocks). The first-order system is given by

$$A_1 V = A_2 E[V] + A_4 \xi + O\left(\epsilon^2\right) \tag{71}$$

from which is follows that

$$E[V] = 0 + O\left(\epsilon^2\right) \tag{72}$$

and

$$V = A_1^{-1} A_4 \xi + O\left(\epsilon^2\right) \tag{73}$$

so

$$E[VV'] = A_1^{-1} A_4 E[\xi\xi'] (A_1^{-1} A_4)' + O\left(\epsilon^3\right) \tag{74}$$

where

$$E[\xi\xi'] = \sigma^2 \begin{bmatrix} 1 & \upsilon \\ \upsilon & 1 \end{bmatrix}$$

The expression for $E[VV']$ given in (74) can be used to construct the elements of $E[\Lambda]$. The resulting expression for $E[\Lambda]$ can be substituted into (70) to yield an expression for $E[V]$ in terms of the exogenous variables and parameters of the model.

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	θ			
	4/5	1	2	4
$\gamma = 1/5$	0.000	0	0.003	0.008
$\gamma = 2/5$	0.002	0	0.009	0.022

Table 1: Flexible prices: The welfare gains from fiscal cooperation for different values of θ (the elasticity of substitution between home and foreign goods) and different values of γ (the share of government spending in total demand). Welfare gains are measured in terms of equivalent changes in consumption as a percentage of consumption in the non-stochastic equilibrium.

	θ			
	4/5	1	2	4
$\gamma = 1/5$	0.003	0	-0.003	-0.003
$\gamma = 2/5$	-0.012	0	-0.010	-0.009

Table 2: The welfare effects of fiscal cooperation when monetary policy is set non-cooperatively for different values of θ (the elasticity of substitution between home and foreign goods) and different values of γ (the share of government spending in total demand). Welfare effects are measured in terms of equivalent changes in consumption as a percentage of consumption in the non-stochastic equilibrium.

		θ			
		4/5	1	2	4
Nash	$\gamma = 1/5$	0.002	0	0.023	0.145
Fiscal Policy	$\gamma = 2/5$	0.006	0	0.041	0.217
Cooperative	$\gamma = 1/5$	0.000	0	0.029	0.156
Fiscal Policy	$\gamma = 2/5$	0.021	0	0.060	0.249

Table 3: The welfare effects of monetary cooperation for different values of θ (the elasticity of substitution between home and foreign goods) and different values of γ (the share of government spending in total demand). Welfare gains are measured in terms of equivalent changes in consumption as a percentage of consumption in the non-stochastic equilibrium. The first two rows show the welfare effects of monetary policy cooperation when fiscal policy is set non-cooperatively and the second two rows show the welfare effects of monetary policy cooperation when fiscal policy is set cooperatively.

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