International Monetary Policy Coordination and Financial Market Integration*

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Abstract

This paper analyses the implications of financial market structure for the existence and size of welfare gains from international monetary policy coordination. Policy coordination is analysed in a two-country stochastic general equilibrium model which is simple enough to yield explicit analytical solutions. Welfare gains from coordination are found to be largest when: the elasticity of substitution between home and foreign goods differs from unity; international markets in state-contingent assets allow full consumption risk sharing; and asset trade takes place before monetary policy rules are determined. Welfare gains are found to be much smaller when there are no international financial markets.
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1 Introduction

The economic interdependence resulting from global integration potentially creates welfare benefits from international policy coordination. One of the most important aspects of global economic integration is the increasing sophistication of international financial markets. It is often argued therefore that increased financial market integration raises the potential benefits from policy coordination (particularly monetary policy coordination). In order to investigate this proposition this paper analyses the implications of international financial market structure for the existence and size of welfare gains from monetary policy coordination.

Welfare gains from policy coordination potentially arise when there are international spillover effects of policy (i.e. where policy in one country has an impact on economic outcomes in another country). There are two reasons for assuming that financial market structure has implications for the spillover effects of monetary policy. First, the effects of monetary policy in an open economy depend to a great extent on the impact of monetary policy on the nominal exchange rate. This link is heavily influenced by the structure of international financial markets. Second, international financial markets play an important role in allowing agents in different countries to share country specific risks. This creates an additional reason to suppose that the structure of financial markets influences the spillover effects of monetary policy.

The implications of financial market structure, in turn, depend to a great extent on the degree of international substitutability between goods produced in different countries. The degree of substitutability (or, more specifically, the elasticity of substitution) matters also for two reasons. First, it determines the strength of the 'expenditure switching effect' of exchange rate changes and therefore determines the impact of monetary policy on goods demand in different countries. It therefore plays a crucial role in the way financial markets transmit the effects of monetary policy from one country to another. Second, the elasticity of substitution influences the degree to which countries are subject to asymmetric income shocks. If the elasticity of substitution is close to unity then relative price changes are largely offset by changes in output volumes. Asymmetric income shocks are therefore small and financial markets are relatively unimportant. On the other hand, when the elasticity of substitution is significantly different from unity, asymmetric income shocks are larger and the risk-sharing role of financial markets is much more important.

Given the interplay between the international elasticity of substitution (i.e. the expenditure switching effect) and financial market structure, this paper jointly investigates their implications for the existence and size of welfare gains to monetary policy coordination. A two-country model is analysed where the elasticity of substitution (in utility) between the bundles of goods produced in the home and foreign countries can differ from unity. The impact of financial market structure is analysed in this model by comparing financial autarky with cases where full consumption risk sharing is possible via trade in state-contingent assets.

The analysis shows that gains from coordination do indeed arise and that the size of these gains depends on the elasticity of substitution between home and foreign goods. While these gains are found to be quantitatively very small in the financial autarky case, when international trade in state-contingent assets is possible it is found that the gains from coordination can be much larger. The existence of financial markets thus creates additional spillover effects which greatly increase the potential gains from policy coordination. In the case where asset markets exist, two alternative financial market structures are considered - one where asset trade takes place after policy is determined and one where asset trade takes place before policy is determined. The welfare gains from policy coordination are found to be greatest when asset trade takes place before policy is determined.

The paper proceeds as follows. Section 2 describes the recent literature on monetary policy coordination and discusses the distinctive contribution of this paper. Section 3 presents the basic structure of the model. Section 4 describes the structure of international financial markets. Section 5 discusses the welfare measure used in this paper. Section 6 analyses the gains from policy coordination in the special case where utility is logarithmic in consumption and linear in labour effort. Section 7 briefly considers some more general cases. Section 8 concludes the paper.

2 Related Literature

The potential welfare gain from international coordination of monetary policy has been a long-standing focus of analysis in international macroeconomics (see for instance Hamada (1976), Canzoneri and Henderson (1991), Currie and Levine (1984), Miller and Salmon (1984), Oudiz and Sachs (1984) and Rogoff (1985)). Recently attention has returned to this topic following the development of new approaches to analysing the welfare effects of monetary policy in closed and open economies. The 'new open economy macroeconomics' literature emphasises the use of microfounded models and utility-based welfare measures and thus offers a more rigorous theoretical framework for analysing this topic.[1] Some of the most relevant recent contributions to the policy coordination literature are briefly surveyed here.

Recent contributions have shown that welfare gains from monetary policy coordination can arise in a range of different cases. Benigno (2002) compares coordinated and non-coordinated monetary policy in a non-stochastic two-country model where monetary policy takes the form of a one-shot unanticipated monetary expansion. Benigno shows that welfare gains from coordination arise when utility is not logarithmic in consumption. Corsetti and Pesenti (2001b) analyse the gains from monetary policy coordination in a stochastic two-country model where there is incomplete pass-through from exchange rate changes to local currency prices. They show that gains to coordination exist when the degree of pass-through is strictly between zero and unity. Devereux and Engel (2003) also analyse the implications of pass-through for the gains from coordination, but they focus on the extreme cases of zero and full pass-through. In these two cases there are no gains from coordination in their model. Obstfeld and Rogoff (2002) analyse a stochastic two-country model with non-traded goods and show that there can be gains from coordination when the coefficient of relative risk aversion is different from unity. Clarida, Gali and Gertler (2002) derive a similar result in a model where goods prices are subject to non-optimal 'cost-push' shocks.

There has been some debate about the likely magnitude of the gains from coordination. Obstfeld and Rogoff (2002) argue that the gains are likely to be very small. A simple calibration exercise using their model suggests that the gains from coordination are almost zero for likely values of the coefficient of relative risk aversion. Canzoneri, Cumby and Diba (2001) on the other hand, suggest that many of the recent contributions to the literature focus on very special cases which tend to greatly understate the possible gains from coordination. They argue that the gains from coordination will be much higher when monetary policy can not achieve the first-best outcome. This will be the case, for instance, when different sectors in the economy are subject to asymmetric shocks or when there are different forms of nominal rigidity in different sectors.

Many of the recent contributions to the literature have focused on simple analytical models where the gains from coordination arise from a single identifiable mechanism. Pappa (2002) and Tchakarov (2002), on the other hand, analyse relatively complex calibrated dynamic models where there are many mechanisms which potentially give rise to gains from coordination. Both authors show that, for some plausible parameter combinations, the gains from coordination can be non-trivial.

An important feature of many of the above cited contributions is that they are based on models where the elasticity of substitution between home and foreign goods is restricted to unity. The models used in these papers are therefore not useful for analysing the implications of the expenditure switching effect for the gains from policy coordination. Indeed, not only does the unit elasticity assumption rule out an analysis of the expenditure switching effect, it also turns out to be a special case where a potential source of welfare gains from coordination is excluded.[2] As

[1] See for instance Corsetti and Pesenti (2001a), Devereux and Engel (2003) and Obstfeld and Rogoff (1995, 1998, 2002). A recent survey of the literature is provided by Lane (2001).

[2] Benigno and Benigno (2003a) are able to show that gains from coordination will arise when the elasticity of substitution differs from unity but they are not able to analyse these gains directly. Tille (2001) analyses the role of the elasticity of substitution between home and foreign goods in the international transmission of shocks. He shows, using a deterministic model, that monetary policy can have a positive or a negative impact on foreign welfare depending on the degree of international substitutability. However, he does not analyse the difference between coordinated and non-coordinated policy. Benigno and Benigno (2003b) analyse coordinated policy in a model where

already indicated, the current paper directly addresses the role of the expenditure switching effect by analysing a model where the elasticity of substitution between home and foreign goods differs from unity. In this important respect, the fundamental structure of the model in the current paper departs from most recent contributions to the literature. In the existing literature only Pappa (2002) and Tchakarov (2002) directly analyse the welfare gains from coordination in models where the elasticity of substitution differs from unity. But these authors focus on numerical analysis of relatively complex dynamic models. The current paper focuses on a simple analytical model which isolates and shows explicitly the role of the expenditure switching effect in generating gains from coordination.

A second important feature of the existing literature is that the role of financial market structure is not analysed. As already emphasised, Benigno (2002), Canzoneri, Cumby and Diba (2001), Clarida, Gali and Gertler (2002), Corsetti and Pesenti (2001b), Devereux and Engel (2003) and Obstfeld and Rogoff (2002) all analyse models where the elasticity of substitution between home and foreign goods is unity. This assumption tends to restrict the role of financial markets. In the cases where financial markets are relevant all the above authors (with the exception of Obstfeld and Rogoff (2002)) assume that full consumption risk sharing is possible through trade in state-contingent assets. Pappa (2002) and Tchakarov (2002), who consider models where the elasticity of substitution can differ from unity, also assume that complete consumption risk sharing is possible. In contrast to other authors, Obstfeld and Rogoff (2002) assume in their model that international financial markets do not exist.

None of the above cited contributions compares different financial market structures.[3] And, when financial markets are assumed to exist, it is universally assumed that trade in state-contingent assets takes place before policy rules are chosen. There is thus no analysis of asset market timing. The current paper compares three possible asset market assumptions. Financial autarky (which corresponds to the Obstfeld and Rogoff (2002) structure), state-contingent asset trade which takes place after the choice of monetary policy (which is not analysed by any of the above cited papers) and state-contingent asset trade which takes place before the choice of monetary policy (which, with the exception of Obstfeld and Rogoff (2002), corresponds to the assumption in all of the above cited papers). The results reported in this paper show that asset market structure can have significant effects on the welfare gains from policy coordination.

A constraint that has hitherto hampered progress in analysing the role of the expenditure switching effect (and therefore also hampered the analysis of financial market structure) is that it is not possible to obtain explicit and exact solutions to stochastic open economy models when the elasticity of substitution between home and foreign goods differs from unity. This paper adopts a second-order approximation technique to overcome this problem. Second-order accurate solutions for welfare are obtained for the general case where the elasticity of substitution differs from unity. This allows explicit solutions for the coordinated and non-coordinated policy rules to be obtained and explicit expressions for the welfare yielded by coordinated and non-coordinated policy to be derived. It is therefore possible to trace the spillover effects which give rise to gains from policy coordination and to analyse the role of the expenditure switching effect and the structure of financial markets in generating these gains.

Pappa (2002), Tchakarov (2002) and Clarida, Gali and Gertler (2002) also use second-order approximation techniques to analyse the welfare gains of coordination. However, both Pappa (2002) and Clarida, Gali and Gertler (2002) make special assumptions which result in a number of terms being omitted from the approximated welfare expressions. This paper shows that these

the elasticity differs from unity and show that the optimal coordinated policy can be sustained by non-coordinated policymakers implementing simple targeting rules.

[3] Benigno (2001) analyses the implications of financial market structure for optimal coordinated policy. He compares an incomplete financial market (where trade is restricted to non-contingent bonds) with full risk sharing. Devereux (2001) also considers the implications of financial market structure. He compares the welfare implications of fixed and flexible exchange rates in the cases of financial autarky and full risk sharing. Neither Benigno (2001) nor Devereux (2001) analyse the difference between coordinated and non-coordinated policy.

terms can have an important influence on the performance of non-coordinated monetary policy. Only Tchakarov (2002) fully implements a true second-order solution technique. As already stated, however, he focuses exclusively on numerical solutions of a relatively complex dynamic model. His analysis therefore does not yield the insights gained from the explicit analytical solutions obtained in this paper.[4]

3 The Model

The basic structure of the model used in this paper is now described. The model closely resembles the structure adopted by Obstfeld and Rogoff (2002). The main differences compared to their framework are that the elasticity of substitution between home and foreign goods may differ from unity and (in the non-financial-autarky cases) international trade in state-contingent assets is possible. As already emphasised, the model described here is intended to focus specifically on the roles of the expenditure switching effect and financial market structure in generating gains from coordination. The model therefore excludes some of the features emphasised by other authors. Thus, for instance, there are no non-traded goods, there are no 'cost-push' or sector-specific shocks and there is full exchange rate pass through.

Market Structure

The world exists for a single period[5] 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. 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. The utility of agent h is given by

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

where $\rho > 0$, $\mu \geq 1$, 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, E is the expectations operator and K is a stochastic labour-supply shock (where $E[\log K] = 0$ and $Var[\log K] = \sigma_K^2 > 0$ and $\log K \in [-\epsilon, \epsilon]$).[6]

[4] Benigno and Benigno (2003b) also make use of second-order approximations to solve their model, but their analysis focuses on the design of simple targeting rules which support the coordinated outcome. They do not analyse in detail the differences between coordinated and non-coordinated policy.

[5] The model can easily be recast as a multi-period structure but this adds no significant insights. A truly dynamic model, with multi-period nominal contracts and asset stock dynamics would require much more extensive use of numerical methods. Newly developed numerical techniques are available to solve such models (see Kim and Kim (2003), Sims (2000), Schmitt-Grohé and Uribe (2004) and Sutherland (2002a)). Tchakarov (2002) uses techniques of this type to analyse a general dynamic model. The approach adopted in the present paper, however, yields useful insights which are not available in more complex models.

[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_K must be less than or equal to ϵ.

The foreign economy is subject to labour-supply shocks (denoted K^*) of the same form as the home economy. For simplicity it is assumed that the variances of the shocks are identical across the two countries, i.e. $\sigma_K^2 = \sigma_{K^*}^2$. 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

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

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 $\phi > 1$, $c_H(i)$ is consumption of home good i and $c_F(j)$ is consumption of foreign good j. The parameter θ is the elasticity of substitution between home and foreign goods. This is the key parameter which will be the focus of analysis in later sections. Although in principle θ may be less than unity, throughout this paper it will be assumed that $\theta \geq 1$.[7] In Obstfeld and Rogoff (2002) θ is fixed at unity.

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, $p_H(h)$ 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.[8]

The government's budget constraint is

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

where P_H is the aggregate price of home produced goods and Y is the aggregate output of the home economy, defined as follows

$$Y = C_H + C_H^* \tag{6}$$

where C_H^* is aggregate foreign demand for home goods.

Price Indices

The aggregate consumer price index for home agents is

$$P = \left[\frac{1}{2} P_H^{1-\theta} + \frac{1}{2} P_F^{1-\theta} \right]^{\frac{1}{1-\theta}} \tag{7}$$

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

$$P_H = \left[\int_0^1 p_H(i)^{1-\phi} di \right]^{\frac{1}{1-\phi}}, \quad P_F = \left[\int_0^1 p_F(j)^{1-\phi} dj \right]^{\frac{1}{1-\phi}} \tag{8}$$

[7] It is useful for expositional purposes to focus on the $\theta > 1$ case. It is also likely that empirically this is the most relevant range. Nevertheless, all of the mechanisms discussed in this paper also operate when θ is less than unity. The only difference is that they operate with a reversed sign. Thus, for instance, in cases where non-coordinated policy generates suboptimally low output volatility when $\theta > 1$, it will generate suboptimally high output volatility when $\theta < 1$. In both cases there will be positive welfare gains from policy coordination.

[8] 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. In the main analysis it proves convenient to set the subsidy so that the distortions created by monopoly are completely offset and average output is at its first-best level. The implications of relaxing this assumption are discussed in Section 7.

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, $P = P^*S$.

Consumption Choices

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

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

where

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

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

$$c_H^*(h) = C_H^*\left(\frac{p_H^*(h)}{P_H^*}\right)^{-\phi}, \quad c_F^*(f) = C_F^*\left(\frac{p_F^*(f)}{P_F^*}\right)^{-\phi} \tag{11}$$

where

$$C_H^* = \frac{1}{2}C^*\left(\frac{P_H^*}{P^*}\right)^{-\theta}, \quad C_F^* = \frac{1}{2}C^*\left(\frac{P_F^*}{P^*}\right)^{-\theta} \tag{12}$$

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

Money Demand and Supply

The first order condition for the choice of money holdings is

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

It is assumed that 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 will take the form

$$M = M_0 K^{\delta_K} K^{*\delta_{K^*}} \text{ and } M^* = M_0^* K^{\delta_K^*} K^{*\delta_{K^*}^*} \tag{14}$$

The feedback parameters δ_K, δ_{K^*}, δ_K^* and $\delta_{K^*}^*$ are chosen by policymakers before prices are set and shocks are realised. It is assumed that policymakers are able to commit to their choice of rule.[9]

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 $\Phi = \phi/[(\phi-1)(1+\alpha)]$. The first-order condition for price setting implies the following

$$P_H = \Phi\frac{E[KY^\mu]}{E[Y/(PC^\rho)]} \tag{15}$$

[9] As discussed in Corsetti and Pesenti (2001b) and Benigno and Benigno (2003a), policymakers face an *ex post* temptation to deviate from any pre-announced policy rule. This can generate either an inflationary or a deflationary bias depending on the balance between the monopoly distortion, the production subsidy and other factors affecting the expected level of output and the terms of trade. In this paper the complications arising from these issues are avoided by assuming that policymakers can commit to the *ex ante* choice of policy rules.

Notice that prices will contain a form of risk premium which depends on the variances and co-variances of the variables on the right hand side of (15). The risk premium reflects the fact that prices are set before shocks are realised. This risk premium plays a role in the link between shocks, monetary policy and welfare. An increase in the variance of KY^{μ} for instance will (other things being equal) increase the risk premium and therefore increase the price of home produced goods. This lowers the expected output of home goods and therefore reduces the expected work effort of home agents and the expected level of consumption for both home and foreign agents. Home and foreign welfare is therefore affected. Monetary policy can be used to affect the variances and covariances which determine the risk premium and can therefore also affect welfare.

4 Financial Markets

The model is closed with an assumption about the structure of international financial markets.

Financial Autarky

When there is no international financial market the portfolio payoffs must be zero by definition, i.e. $R(h) = R^*(f) = 0$ for all h and f. Thus the current account must balance in all states of the world, i.e.

$$P_H C_H^* = S P_F^* C_F \tag{16}$$

where $P_H C_H^*$ is the value of home sales to the foreign country and $S P_F^* C_F$ is the value of foreign sales to the home country (where both amounts are valued in terms of the home currency).

Integrated Financial Markets

In the case where an international financial market exists it is assumed that sufficient contingent financial instruments are available to allow efficient sharing of consumption risks.

It is important to specify the point in time at which asset trade takes place. There are two possible structures. In the first structure asset markets open *before* policymakers have made their choice of monetary policy rules. In the second structure asset markets open *after* policy rules have been chosen. (In this second structure it is assumed that asset trade takes place at the same time as goods prices are set.) It will become apparent below that the second structure implies a more limited form of insurance because agents can not insure against the choice of policy rules - they can only insure against the risk implied by a particular pair of rules.

It will also become apparent that the distinction between the two risk-sharing structures is important from the point of view of policymakers. In the second structure policymakers are aware that agents are not fully insured against the potential negative impact of the choice of policy rule. Policymakers therefore internalise these costs. This contrasts with the first structure where policymakers do not fully internalise the costs of policy rule choice. Not surprisingly this can greatly increase the cross-country spillover effects of monetary policy and can generate potentially large welfare gains from monetary policy coordination. The two alternative risk-sharing cases are analysed separately.[10]

The contrast between the two assumptions about the timing of asset trade can be understood more clearly by considering the structure of asset markets explicitly. The only source of consumption risk faced by consumers is variability in real 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 income and one with a payoff correlated with foreign real income. For simplicity it is assumed that each asset pays a return equal to the relevant country's real income, i.e. a

[10] An earlier version of this paper (Sutherland (2002b)) focused only on the case where asset trade takes place after policy rules are chosen. In that version of the paper the contingent assets necessary to support risk sharing were not modelled explicitly. It was argued that the contingent assets necessary to allow insurance against the choice of policy rule would be implausibly complicated. The new structure adopted here makes it clear that a simple and plausible asset structure which allows agents to insure against the choice of policy rules does indeed exist.

unit of the home asset pays y and a unit of the foreign asset pays y^* where $y = YP_H/P$ and $y^* = Y^*P_F/P$. The portfolio payoffs for home and foreign agents are given by the following

$$R(h) = \zeta_H(h)(y - q_H) + \zeta_F(h)(y^* - q_F) \tag{17}$$

$$R^*(f) = \zeta_H^*(f)(y - q_H) + \zeta_F^*(f)(y^* - q_F) \tag{18}$$

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.[11]

It is shown in the Appendix that, regardless of the timing of asset trade, equilibrium in the asset market implies

$$\frac{C}{C^*} = \frac{q_H}{q_F} \tag{19}$$

and that equilibrium asset prices are given by

$$q_H = \frac{E\left[\frac{y}{(y+y^*)^\rho}\right]}{E\left[\frac{1}{(y+y^*)^\rho}\right]}, \qquad q_F = \frac{E\left[\frac{y^*}{(y+y^*)^\rho}\right]}{E\left[\frac{1}{(y+y^*)^\rho}\right]} \tag{20}$$

It is important to note that, while the form of the above relationships is unaffected by the timing of asset trade, the information set relevant for the expectational terms in (20) does depend on the timing of asset trade.

In the case where asset trade takes place before policy decisions are made the expectations in (20) must be formed without knowledge of the policy rules chosen by policymakers. Notice, however, that the asset pricing problem only requires agents to form a view on relative output levels. Given the symmetric structure of the model it seems reasonable to suppose that agents will forecast a symmetric equilibrium (including a symmetric equilibrium to the policymaking game) so that (in expectation) $y = y^*$. This is a sufficient condition to imply that $q_H = q_F$ and thus $C = C^*$.

On the other hand, in the case where asset trade takes place after policy decisions are made, asset prices will be determined with full knowledge of the chosen policy rules. Asset prices will again be given by (20) but now expectations will be conditional on information available after policy rules are chosen.

When considering the implications for policymaking the important point to note is that, when asset trade takes place before policy rules are chosen, asset prices will be treated by policymakers as *exogenous*. Each policymaker will therefore make a policy decision while knowing that $C = C^*$ for all states of the world and all possible combinations of home and foreign policy rules. In this sense consumption levels in each country will be fully insured against the (asymmetric) choice of policy rules.

On the other hand, in the case where asset trade takes place after policy decisions are made asset prices must be treated by policymakers as *endogenous*. And it is clear from (20) that asset prices (and thus relative consumption levels) will depend on the chosen policy rules. Thus, for instance, if the home policymaker adopts a policy rule which depresses the expected level of home income relative to foreign income then (other things being equal) q_H/q_F must be less than unity, and 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 the home policymaker from adopting policy rules which depress home income.[12] This welfare cost does not arise in the case where asset trade takes place before policy rules are chosen.

[11] It is important to emphasise that trade in income contingent assets is only sufficient to allow full sharing of consumption risk. It does not allow agents to share work-effort risk. And it does not allow agents to undo the constraints of nominal price contracts. The situation modelled here is therefore *not* one of 'complete markets'.

[12] In a symmetric world the actual Nash equilibrium of the policymaking game will give rise to a symmetric equilibrium where both policymakers choose the same policy rule. In turn this implies that $q_H/q_F = 1$ and $C = C^*$ in equilibrium regardless of the timing of asset trade. But in considering the optimal strategy of a Nash player it is necessary to consider the implications of asymmetric policy choices even though these choices are not implemented in equilibrium.

5 Welfare

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

$$\Omega = E\left[\frac{C^{1-\rho}}{1-\rho} - \frac{K}{\mu}Y^{\mu}\right] \tag{21}$$

The expectations operator in this expression obviously denotes expectations conditional on information available at the time at which policy decisions are made.[13]

It is not possible to derive an exact expression for welfare (except in special cases). The complication arising in this model (which does not arise in other models used in the recent literature) is contained in equations (6) and (7). When θ is not equal to unity neither of these equations is linear in logs. 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.

Define the non-stochastic equilibrium of the model to be the solution which results when $K = K^* = 1$ with $\sigma_K^2 = \sigma_{K^*}^2 = 0$ and for any variable X define $\hat{X} = \log(X/\bar{X})$ where $\bar{X}$ is the value of variable X in the non-stochastic equilibrium. A second-order approximation of the welfare measure is given by

$$\tilde{\Omega} = E\left\{\bar{C}^{1-\rho}\left[\hat{C} + \frac{1}{2}(1-\rho)\hat{C}^2\right] - \bar{Y}^{\mu}\left[\hat{Y} + \frac{\mu}{2}\left(\hat{Y} + \frac{\hat{K}}{\mu}\right)^2\right]\right\} + O\left(\epsilon^3\right) \tag{22}$$

where $\tilde{\Omega}$ is the deviation of welfare from the non-stochastic equilibrium and the term $O(\epsilon^3)$ contains all terms of third order and higher in deviations from the non-stochastic equilibrium.[14]

Using the price setting condition (15) it is simple to show that $\bar{Y}^{\mu} = \bar{C}^{1-\rho}/\Phi$. It is therefore possible to write welfare as follows

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

6 Welfare Gains from Coordination in a Simplified Model

The main analysis in this paper focuses on a simplified version of the above model where utility is logarithmic in consumption and linear in work effort. In this case the coefficient of relative risk aversion, ρ, and the parameter μ are set equal to unity. It also proves useful to set the production subsidy, α, so that the monopolistic distortion is completely offset. This implies $\Phi = 1$. These parameter restrictions make it possible to isolate some of the important mechanisms generating gains from coordination. The implications of relaxing these simplifying assumptions are discussed in Section 7.

The three simplifying assumptions make it possible to write welfare as follows

$$\tilde{\Omega} = E\left[\hat{C} - \hat{Y} - \frac{1}{2}\left(\hat{Y} + \hat{K}\right)^2\right] + O\left(\epsilon^3\right) \tag{24}$$

[13] Policy decisions are made before goods prices are set. However, given that no events take place between the choice of policy rules and the setting of goods prices, policymakers effectively have the same information set as price setters. This implies that goods prices are perfectly forecastable by policymakers. In the case where asset trade takes place after policy decisions are made, asset prices will also be perfectly forecastable by policymakers.

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

Thus welfare depends positively on the expected log-deviation of consumption and negatively on the expected log-deviation of output. The intuitive explanation for these first-order effects is obvious - utility is increasing in consumption and decreasing in work effort. The explanation for the quadratic term in $(\hat{Y}+\hat{K})$ is, however, slightly less obvious. When $\mu = 1$ agents are risk neutral in terms of work effort. It may therefore seem odd that welfare is decreasing in the variance of $(\hat{Y}+\hat{K})$. However, note that the term KY in the non-approximated welfare function (21) is convex in the log-deviations of Y and K so (because of Jensen's inequality) the expected value of KY must be increasing in the variance of $(\hat{Y}+\hat{K})$. This gives rise to the quadratic term in (24).

It will become apparent below that a number of import mechanisms can be explained in terms of the behaviour of $\hat{Y}+\hat{K}$ and $\hat{Y}^*+\hat{K}^*$. In what follows $\hat{Y}+\hat{K}$ will be referred to as 'the disutility of home work effort'. Likewise $\hat{Y}^*+\hat{K}^*$ will be referred to as 'the disutility of foreign work effort'.

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

$$\tilde{\Omega} = \tilde{\Omega}_W + \tilde{\Omega}_R, \qquad \tilde{\Omega}^* = \tilde{\Omega}_W - \tilde{\Omega}_R \tag{25}$$

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

$$\tilde{\Omega}_W = \frac{1}{2}E[(\hat{C}+\hat{C}^*) - (\hat{Y}+\hat{Y}^*) - \frac{1}{2}(\hat{Y}+\hat{K})^2 - \frac{1}{2}(\hat{Y}^*+\hat{K}^*)^2] + O\left(\epsilon^3\right) \tag{26}$$

and

$$\tilde{\Omega}_R = \frac{1}{2}E[(\hat{C}-\hat{C}^*) - (\hat{Y}-\hat{Y}^*) - \frac{1}{2}(\hat{Y}+\hat{K})^2 + \frac{1}{2}(\hat{Y}^*+\hat{K}^*)^2] + O\left(\epsilon^3\right) \tag{27}$$

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

The welfare effects of policy coordination will now be considered for each of the financial market structures in turn. The model solution technique will be explained in the context of the financial autarky case.

6.1 Financial Autarky

Notice that, to evaluate welfare, it is necessary to obtain second-order accurate expressions for both the first and second moments of output and consumption. Second-order accurate expressions for second moments can easily be obtained from a first-order approximation of the model. But to derive second-order accurate solutions for first moments it is necessary to solve a second-order approximation of the model. The Appendix describes a simple two-step procedure which yields the required solutions.

Before applying the procedure it is necessary to derive second-order approximations to the model's equations. Approximations are only required for the equations defining home and foreign output, home and foreign consumer prices and home and foreign output prices. All the other relationships in the model are linear in logs so no approximation is required.

Second-order approximations for the home and foreign output levels are

$$\hat{Y} = \frac{1}{2}(\hat{C}+\hat{C}^*) - \frac{\theta}{2}\hat{\tau} + \lambda_Y + O(\epsilon^3), \quad \hat{Y}^* = \frac{1}{2}(\hat{C}+\hat{C}^*) + \frac{\theta}{2}\hat{\tau} + \lambda_Y + O(\epsilon^3) \tag{28}$$

where

$$\lambda_Y = \frac{1}{8}(\hat{C}-\hat{C}^*)^2 \tag{29}$$

Second-order approximations for the home and foreign consumer price indices are

$$\hat{P} = \frac{1}{2}\hat{P}_H + \frac{1}{2}(\hat{P}_F^* + \hat{S}) + \lambda_P + O(\epsilon^3), \quad \hat{P}^* = \frac{1}{2}(\hat{P}_H - \hat{S}) + \frac{1}{2}\hat{P}_F^* + \lambda_P + O(\epsilon^3) \tag{30}$$

where

$$\lambda_P = \frac{1}{8}(1-\theta)\hat{S}^2 \tag{31}$$

And second-order approximations for the home and foreign price-setting conditions are

$$\hat{P}_H = E[\hat{K}+\hat{P}+\hat{C}] + \lambda_{P_H} + O(\epsilon^3), \qquad \hat{P}_F^* = E[\hat{K}^* + \hat{P}^* + \hat{C}^*] + \lambda_{P_F^*} + O(\epsilon^3) \tag{32}$$

where

$$\lambda_{P_H} = \frac{1}{2}E[(\hat{K}+\hat{Y})^2 - (\hat{Y}-\hat{P}-\hat{C})^2], \qquad \lambda_{P_F^*} = \frac{1}{2}E[(\hat{K}^*+\hat{Y}^*)^2 - (\hat{Y}^*-\hat{P}^*-\hat{C}^*)^2] \tag{33}$$

Solutions for First Moments

It is apparent that the approximated model gives rise to four 'second-order terms' λ_Y, λ_P, λ_{P_H} and $\lambda_{P_F^*}$. The first step in the solution process outlined in the Appendix generates expressions for the first moments of the variables of the model in terms of these second-order terms. In the financial autarky case the following expressions for the first moments of C, C^*, Y and Y^* are obtained:

$$E[\hat{C}] = E[\frac{\hat{\tau}}{2\theta} - \lambda_P] - \lambda_{P_H} + O(\epsilon^3) \tag{34}$$

$$E[\hat{C}^*] = E[-\frac{\hat{\tau}}{2\theta} - \lambda_P] - \lambda_{P_F^*} + O(\epsilon^3) \tag{35}$$

$$E[\hat{Y}] = -\lambda_{P_H} + E[\lambda_Y - (1-\theta)\lambda_P] + O(\epsilon^3) \tag{36}$$

$$E[\hat{Y}^*] = -\lambda_{P_F^*} + E[\lambda_Y - (1-\theta)\lambda_P] + O(\epsilon^3) \tag{37}$$

where

$$E[\hat{\tau}] = \frac{\lambda_{P_H} - \lambda_{P_F^*}}{\theta} + O(\epsilon^3) \tag{38}$$

where τ is the terms of trade (i.e. $\tau \equiv P_H/P_F$).

It is useful at this point to consider the economic interpretation of the four second-order terms, λ_Y, λ_P, λ_{P_H} and $\lambda_{P_F^*}$ (defined in (29), (31) and (33)), and their impact on the first moments of consumption, output and the terms of trade as revealed by (34) to (38).

λ_{P_H} and $\lambda_{P_F^*}$ have the most straightforward interpretation. These terms are effectively the risk premia that are built into home and foreign goods prices. Notice that (other things being equal) λ_{P_H} is increasing in the variance of the disutility of home work effort (i.e $\hat{Y}+\hat{K}$) and $\lambda_{P_F^*}$ is increasing in the variance of the disutilily of foreign work effort (i.e. $\hat{Y}^*+\hat{K}^*$). From (34) to (38) it can be seen that an equal increase in λ_{P_H} and $\lambda_{P_F^*}$ causes a fall in expected output and consumption for both countries. This reflects the fact that a higher level of risk faced by producers reduces desired work effort and therefore reduces the resources available for consumption. On the other hand, a rise in λ_{P_H} relative to $\lambda_{P_F^*}$ causes a decrease in home output relative to foreign output (see equations (36) and (37)) which shifts the expected terms of trade to the advantage of home agents (see equations (38)). This allows home agents to consume more relative to foreign agents. It will become apparent below that these effects have important implications for non-coordinated monetary policy.

λ_P arises because of the non-log-linearity of the consumer price index. Notice that $E[\lambda_P]$ is negatively related to volatility in the nominal exchange rate (when $\theta > 1$). Other things being equal a decrease in $E[\lambda_P]$ increases the expected levels of both home and foreign consumption and reduces the expected levels of home and foreign output (provided $\theta > 1$). This can be understood by considering the definition of the consumer price index. When $\theta > 1$ the consumer price index is concave in the price of home and foreign goods so any volatility in the relative price of home and foreign goods (which results from exchange rate volatility) reduces the expected cost of the consumption basket. (Another way to understand this effect is to note that, when home and foreign goods are substitutable, agents can reduce the average cost of their consumption basket by switching expenditure towards whichever set of goods is cheapest *ex post*.)

λ_Y arises because of the non-log-linearity of the aggregate output relationship and appears merely to be an artefact of the approximation process.[15] Other things being equal, an increase in $E[\lambda_Y]$ raises the expected levels of both home and foreign output.

The above expressions for first moments are obviously not full reduced forms because it is also necessary to derive expressions for λ_Y, λ_P, λ_{P_H} and $\lambda_{P_F^*}$. But notice that λ_Y, λ_P, λ_{P_H} and $\lambda_{P_F^*}$ are themselves (in expectation) linear combinations of the second moments of the variables of the model. So full reduced-form expressions for first moments can be obtained once expressions for second moments have been derived. This is the second step in the solution process.

Solutions for Realised Values

As already noted, second-order accurate expressions for second moments can be obtained from first-order accurate solutions for the realised values of endogenous variables. First-order accurate solutions are therefore now derived.

First note that the assumption of pre-fixed prices implies that (to a first order) the realised log-deviations of home and foreign goods prices are given by

$$\hat{P}_H = \hat{P}_F^* = 0 + O\left(\epsilon^2\right) \tag{39}$$

where $O\left(\epsilon^2\right)$ represents all terms of order two and above. It therefore follows that home and foreign consumer prices are given by

$$\hat{P} = \frac{1}{2}\hat{S} + O\left(\epsilon^2\right), \quad \hat{P}^* = -\frac{1}{2}\hat{S} + O\left(\epsilon^2\right) \tag{40}$$

When these expressions are combined with the demands for home and foreign goods it is simple to show that home and foreign aggregate outputs are given by

$$\hat{Y} = \frac{1}{2}(\hat{C} + \hat{C}^*) + \frac{\theta}{2}\hat{S} + O\left(\epsilon^2\right) \tag{41}$$

and

$$\hat{Y}^* = \frac{1}{2}(\hat{C} + \hat{C}^*) - \frac{\theta}{2}\hat{S} + O\left(\epsilon^2\right) \tag{42}$$

Thus aggregate output is determined by aggregate world consumption and the exchange rate. The exchange rate term is the 'expenditure switching effect'. A depreciation of the exchange rate increases demand for home goods and reduces demand for foreign goods. The strength of the expenditure switching effect is determined by θ (which is the elasticity of substitution between home and foreign goods).

Combining the expressions for aggregate prices with the money market equilibrium conditions implies

$$\hat{C} = \hat{M} + \frac{1}{2}\hat{S} + O\left(\epsilon^2\right), \quad \hat{C}^* = \hat{M}^* - \frac{1}{2}\hat{S} + O\left(\epsilon^2\right) \tag{43}$$

so

$$\hat{C} + \hat{C}^* = \hat{M} + \hat{M}^* + O\left(\epsilon^2\right) \tag{44}$$

Thus aggregate world consumption is determined by the sum of home and foreign monetary policy. All the above relationships hold regardless of the structure of financial markets.

Financial markets come into play in the determination of the exchange rate. Using the expressions for aggregate prices and the demands for home and foreign goods, current account balance (which, in the autarky case, holds in all states of the world) implies

$$\hat{S} = \frac{1}{\theta - 1}(\hat{C} - \hat{C}^*) + O\left(\epsilon^2\right) \tag{45}$$

[15] As such λ_Y appears to have no particularly useful economic interpretation. Furthermore it turns out that λ_Y has no implications for the deviation between coordinated and non-coordinated monetary policy.

Thus, when home consumption exceeds foreign consumption, the exchange rate must depreciate in order to maintain current account balance (and vice versa when foreign consumption exceeds home consumption). When this expression is combined with the expressions for aggregate consumption it is found that

$$\hat{S} = \frac{1}{\theta}(\hat{M} - \hat{M}^*) + O\left(\epsilon^2\right) \tag{46}$$

Thus the exchange rate depends on relative money supplies.

When (46) and (44) are substituted into the expressions for aggregate output it is simple to show that

$$\hat{Y} = \hat{M} + O\left(\epsilon^2\right), \quad \hat{Y}^* = \hat{M}^* + O\left(\epsilon^2\right) \tag{47}$$

The important point to note from these expressions is that, in the financial autarky case, monetary policy has no international spillover effects on the realised values of output. A change in home monetary policy only affects home output and a change in foreign monetary policy only affects foreign output. This is because the effects of monetary policy on aggregate world demand are just enough to offset the expenditure switching effect.

The above expressions for the realised values of consumption, output and the exchange rate can now be combined with the previously derived expressions for first moments in order to analyse the welfare effects of coordinated and non-coordinated policymaking.

Coordinated Policy

Coordinated policymaking is defined to be the case where a single world policymaker chooses the feedback coefficients in the home and foreign monetary policy rules in order to maximise world aggregate welfare, $\tilde{\Omega}_W$.

Using the solutions for first moments it is possible to write first-order terms in world welfare as follows

$$\hat{C} + \hat{C}^* - \hat{Y} - \hat{Y}^* = -2\lambda_Y - 2\theta\lambda_P \tag{48}$$

and therefore world welfare can be written as

$$\tilde{\Omega}_W = \frac{1}{2}E\left[-2\lambda_Y - 2\theta\lambda_P - \frac{1}{2}(\hat{Y} + \hat{K})^2 - \frac{1}{2}(\hat{Y}^* + \hat{K}^*)^2\right] + O\left(\epsilon^3\right) \tag{49}$$

Recall that the definitions of λ_Y and λ_P are

$$\lambda_Y = \frac{1}{8}(\hat{C} - \hat{C}^*)^2 \quad \text{and} \quad \lambda_P = \frac{1}{8}\left(1 - \theta\right)\hat{S}^2 \tag{50}$$

and note from (45) that current account balance implies that realised values of consumption and the exchange rate are related as follows

$$\hat{C} - \hat{C}^* = \left(\theta - 1\right)\hat{S} + O\left(\epsilon^2\right) \tag{51}$$

and recall that the realised values of output and the exchange are related to monetary policy by

$$\hat{Y} = \hat{M} + O\left(\epsilon^2\right), \quad \hat{Y}^* = \hat{M}^* + O\left(\epsilon^2\right) \tag{52}$$

and

$$\hat{S} = \frac{1}{\theta}(\hat{M} - \hat{M}^*) + O\left(\epsilon^2\right) \tag{53}$$

The nature of coordinated policy can now be explained quite easily with reference to these equations. Consider first the case where $\theta = 1$. In this case it is simple to see that $\lambda_Y = \lambda_P = 0$. Thus welfare depends only on the two quadratic terms in the welfare function. It is immediately obvious that the optimal coordinated policy is to use the home money supply to stabilise the disutility of home work effort $(\hat{Y} + \hat{K})$ and foreign monetary policy to stabilise the disutility of foreign work effort $(\hat{Y}^* + \hat{K}^*)$.

Now consider the case where $\theta > 1$. A value of θ greater than unity has two effects which work in different directions. One effect works through λ_Y and the other works through λ_P.

When θ is greater than unity λ_Y is greater than zero and positively related to exchange rate volatility. This term therefore creates an incentive to stabilise the exchange rate relative to the case where $\theta = 1$. This arises because, when $\theta > 1$, consumption levels across the two countries are not perfectly correlated. There are thus welfare gains to be achieved by using monetary policy to increase the cross-country correlation of consumption and (in effect) increase the amount of international consumption risk sharing.

On the other hand $\theta > 1$ also implies that λ_P is less than zero and negatively related to exchange rate volatility. The λ_P term in welfare therefore creates an incentive to increase the volatility of the exchange rate relative to the $\theta = 1$ case. This arises because $\theta > 1$ implies that goods are more substitutable than in the $\theta = 1$ case and therefore there are welfare gains to be exploited by shifting demand towards the goods produced by the country with the most favourable labour supply shock. This shift in demand is achieved by depreciating the currency of the country with the most favourable supply shock.

It is simple to show that (for $\theta > 1$) the incentive to increase exchange rate volatility coming from λ_P outweighs the incentive to decrease exchange rate volatility coming from λ_Y. The net result is that (in contrast to the $\theta = 1$ case) the disutility of home and foreign work effort ($\hat{Y} + \hat{K}$ and $\hat{Y}^* + \hat{K}^*$) are not perfectly stabilised by the coordinated policymaker .

It is possible to show that the coordinated equilibrium results in the following choices of feedback parameters

$$\delta_K^C = \delta_{K^*}^{*C} = \frac{-1 + \theta - 2\theta^2}{2\left(1 - \theta + \theta^2\right)} \tag{54}$$

$$\delta_{K^*}^C = \delta_K^{*C} = \frac{-1 + \theta}{2\left(1 - \theta + \theta^2\right)} \tag{55}$$

where the superscript 'C' indicates the coordinated equilibrium. The world welfare level yielded by coordinated policy is

$$\tilde{\Omega}_A^C = \frac{(\theta - 1)}{4\left(1 - \theta + \theta^2\right)}(1 - \upsilon)\sigma_K^2 \tag{56}$$

where the subscript 'A' indicates the financial autarky case.

Non-Coordinated Policy

Non-coordinated monetary policy is defined to be the Nash equilibrium that arises when the home monetary authority chooses the parameters of the home monetary policy rule to maximise home welfare and the foreign monetary policymaker chooses the parameters of the foreign monetary policy rule to maximise foreign welfare. The incentive for each national policymaker to deviate from the coordinated policy can be analysed by considering the expression for relative welfare.

Using the solutions for first moments it is possible to write the first-order terms in relative welfare as follows

$$(\hat{C} - \hat{C}^*) - (\hat{Y} - \hat{Y}^*) = E\left[\hat{\tau}\right] = \frac{\lambda_{P_H} - \lambda_{P_F^*}}{\theta} \tag{57}$$

and thus relative welfare can be written as

$$\tilde{\Omega}_R = \frac{1}{2}E\left[\frac{\lambda_{P_H} - \lambda_{P_F^*}}{\theta} - \frac{1}{2}(\hat{Y} + \hat{K})^2 + \frac{1}{2}(\hat{Y}^* + \hat{K}^*)^2\right] + O\left(\epsilon^3\right) \tag{58}$$

Using (47) and the money market equilibrium relations it follows that the realised values of home and foreign consumption, output and prices imply that

$$\hat{Y} - \hat{P} - \hat{C} = \hat{Y}^* - \hat{P}^* - \hat{C}^* = 0 + O\left(\epsilon^2\right)$$

so the expressions for λ_{P_H} and $\lambda_{P_F^*}$ can be simplified to yield

$$\lambda_{P_H} = \frac{1}{2}E[(\hat{K} + \hat{Y})^2] \tag{59}$$

$$\lambda_{P_F^*} = \frac{1}{2}E[(\hat{K}^* + \hat{Y}^*)^2] \tag{60}$$

First consider the case where $\theta = 1$. It is simple to see that in this case $\tilde{\Omega}_R = 0$. Thus there can be no incentive for non-coordinated policymakers to deviate from the coordinated policy when $\theta = 1$. The non-coordinated and coordinated equilibria will therefore be identical. (As is true in Obstfeld and Rogoff (2002) when utility is logarithmic in consumption).

However, when $\theta > 1$ the relative welfare function shows that non-coordinated policymakers each face two incentives to deviate from the coordinated policy. Consider, for instance, the incentives facing the home policymaker. The quadratic term in $\hat{Y} + \hat{K}$ in the relative welfare expression creates an incentive for the home policymaker to use home monetary policy to stabilise the disutility of home work effort relative to the coordinated policy case. (Recall that the coordinated policymaker does not completely stabilise $\hat{Y} + \hat{K}$ when $\theta > 1$ because there is an incentive to exploit the greater substitutability of goods when $\theta > 1$.) The second incentive to deviate from the coordinated policy comes through the λ_{P_H} term. Here the home policymaker has an incentive to destabilise the disutility of home work effort. By destabilising $\hat{Y} + \hat{K}$ the home policymaker reduces the supply of home goods and thus shifts the expected terms of trade in the favour of the home economy.

Notice that the relative welfare function also contains an incentive for the home monetary authority to attempt to destabilise the disutility of foreign work effort (relative to the coordinated policy) and for the foreign policymaker to attempt to destabilise the disutility of home work effort (again relative to the coordinated policy). These incentives are, however, irrelevant because (in the autarky case) monetary policy in one country does not have any influence on output in the other country.

It is simple to see that the incentive to stabilise $\hat{Y} + \hat{K}$ coming through the quadratic term in $\hat{Y} + \hat{K}$ in the relative welfare expression is stronger than the incentive to destabilise $\hat{Y} + \hat{K}$ coming through λ_{P_H}. This is because the home country's ability to shift the terms of trade in its favour declines as goods become more substitutable (i.e. as θ rises). The net result is, therefore, that, when $\theta > 1$, non-coordinated policymakers tend to use monetary policy to stabilise the disutility of work effort of their own populations relative to the case of coordinated policy. There are thus potential welfare gains from coordinated policy when $\theta > 1$.

Before formally analysing these welfare gains it is worth noting again the mechanism which underlies the difference between coordinated and non-coordinated policy. When $\theta > 1$ the bundles of goods produced in the two countries are relatively good substitutes so the coordinated policymaker chooses monetary rules which (*ex post*) shift production to the country with the most favourable labour supply shock. This creates volatility in output levels but also generates (expected) welfare benefits for both countries. Non-coordinated policymakers, on the other hand, care only about the volatility of work effort of their own population while they do not care about the foreign population's share of the welfare benefit that arises from shifting production to the lowest cost country. Non-coordinated policymakers therefore favour levels of output volatility which are suboptimally low from a global perspective.[16]

It is possible to show that the non-coordinated equilibrium results in the following policy feedback parameters

$$\delta_K^N = \delta_{K^*}^{*N} = \frac{1 - 3\theta + 4\theta^2}{-2\left(1 - 2\theta + 2\theta^2\right)} \tag{61}$$

[16] As previously stated, the analysis focuses on the case where $\theta > 1$. If $\theta < 1$ many of the mechanisms just described work in reverse. Non-coordinated policymakers therefore favour levels of output volatility which are suboptimally high from a global perspective.

$$\delta^N_{K^*} = \delta^{*N}_K = \frac{-1+\theta}{-2\left(1-2\theta+2\theta^2\right)} \tag{62}$$

where the superscript 'N' indicates the non-coordinated equilibrium. The level of world welfare yielded by non-coordinated policy is

$$\tilde{\Omega}^N_A = \frac{\left(-2+7\theta-9\theta^2+4\theta^3\right)}{4\left(1-2\theta+2\theta^2\right)^2}(1-\upsilon)\sigma^2_K \tag{63}$$

where again the subscript 'A' indicates the financial autarky case.

Welfare Effects of Coordination

The following proposition can now be stated. (The proof follows from a simple comparison of the above expressions and is omitted.)

Proposition 1 *If $\upsilon < 1$ and $\theta \neq 1$ then $\tilde{\Omega}^C_A > \tilde{\Omega}^N_A$, i.e. there are welfare gains from policy coordination.*

The gains from coordination disappear in two circumstances. The first case is when $\theta = 1$. This has already been discussed. The second case is where the shocks in the two countries are perfectly correlated, i.e. when $\upsilon = 1$. This corresponds to a result noted and emphasised by Obstfeld and Rogoff (2002). When shocks are perfectly correlated the use of monetary policy to stabilise the disutility of work effort in one country will automatically also stabilise disutility of work effort in the other country. There is therefore no difference between coordinated and non-coordinated policymaking.

Proposition 1 establishes that there are gains to coordination when $\theta \neq 1$. But in order to determine the size of these gains it is necessary to perform some numerical exercises with different values of θ. Table 1 reports some values for welfare with $\sigma^2_K = \sigma^2_{K^*} = 0.01$ and $\upsilon = 0$. A range of values of θ has been suggested in previous literature, for instance Benigno and Benigno (2003a) suggest $\theta = 6$. Table 1 shows welfare calculations for $\theta = 1$ to $\theta = 6$.

As a point of reference it is useful to consider an inactive policy regime, where feedback parameters are all set to zero. The welfare level yielded by this regime is $\tilde{\Omega}^M_A = -\sigma^2_K/2$ where the superscript 'M' indicates the case of non-active policy (or money targeting).

The first row in Table 1 shows the welfare gain from coordinated policy relative to an inactive policy (i.e. $\tilde{\Omega}^C_A - \tilde{\Omega}^M_A$). The figures in the first row therefore represent the maximum possible gain from following an active policy. The second row shows the welfare gain from non-coordinated policy relative to an inactive policy (i.e. $\tilde{\Omega}^N_A - \tilde{\Omega}^M_A$). The third row shows the absolute gains from coordination (i.e. $\tilde{\Omega}^C_A - \tilde{\Omega}^N_A$). In each case these figures are measured as a percentage of (first-best) non-stochastic equilibrium consumption. The fourth row shows the gains from coordination as a percentage of the maximum possible gain from an active policy (i.e. row 3 as a percentage of row 1).

It is apparent from Table 1 that (consistent with Proposition 1) the welfare gain from coordination is positive when θ is greater than unity. But the gain is never large, either in absolute or relative terms. This is very similar to the result emphasised by Obstfeld and Rogoff (2002). Thus, the spillover effects and strategic interaction generated by the expenditure switching effect appear to be relatively unimportant when there are no international financial markets.

6.2 Asset Trade After Monetary Policy

The case where asset markets exist and asset trade takes place after policy decisions is now analysed. The solution procedure is identical to the autarky case and many of the relationships derived above continue to be relevant. The following discussion focuses on the points of divergence from the autarky case.

θ	1	2	4	6
$\tilde{\Omega}_A^C - \tilde{\Omega}_A^M$	0.500	0.583	0.558	0.540
$\tilde{\Omega}_A^N - \tilde{\Omega}_A^M$	0.500	0.580	0.555	0.539
$\tilde{\Omega}_A^C - \tilde{\Omega}_A^N$	0.000	0.003	0.002	0.001
$\frac{100\times\left(\tilde{\Omega}_A^C - \tilde{\Omega}_A^N\right)}{\left(\tilde{\Omega}_A^C - \tilde{\Omega}_A^M\right)}$	0.0	0.6	0.4	0.2

Table 1: The welfare effects of coordination: Financial autarky

First Moments

The approximated equations for national output levels, consumer prices and output prices that were derived in the autarky case continue to be relevant in this case. However, when asset trade takes place after policy rules are chosen it is necessary also to derive second-order approximations of the asset pricing relationships, (20). This yields

$$\hat{q}_H = E\left[\hat{y} + \frac{1-\rho}{2}\hat{y}^2 - \frac{\rho}{2}\hat{y}\hat{y}^*\right], \quad \hat{q}_F = E\left[\hat{y}^* + \frac{1-\rho}{2}\hat{y}^{*2} - \frac{\rho}{2}\hat{y}\hat{y}^*\right]$$

Combining these expressions with (19) and setting $\rho = 1$ implies the following relationship between home and foreign consumption

$$\hat{C} - \hat{C}^* = E\left[(\hat{y} - \hat{y}^*)\right] + O\left(\epsilon^3\right) \tag{64}$$

Notice that this relationship does not give rise to any additional second-order term as long as $\rho = 1$. Using the second-order approximations for national output levels given in (28) it is simple to show that this expression implies that current account balance will hold in expected terms. It therefore follows that the solution for first moments is identical to the autarky case. Thus the expressions given in (34) to (38) continue to apply (when $\rho = 1$).

Realised Values

When an international financial market exists (regardless of the timing of asset trade) consumption levels satisfy equation (19). A first-order expansion of this expression implies[17]

$$\hat{C} - \hat{C}^* = 0 + O\left(\epsilon^2\right) \tag{65}$$

When combined with the money market relationships this implies

$$\hat{S} = \hat{M} - \hat{M}^* + O\left(\epsilon^2\right) \tag{66}$$

This expression should be compared to (46) which shows the determination of the exchange rate in the autarky case. It is clear that, as in the autarky case, the exchange rate depends on relative monetary supplies. But notice that the exchange rate is more sensitive to monetary policy when there is risk sharing (provided $\theta > 1$).

When (44) and (66) are substituted into (41) and (42) the following expressions for national outputs are found

$$\hat{Y} = \frac{1+\theta}{2}\hat{M} + \frac{1-\theta}{2}\hat{M}^* + O\left(\epsilon^2\right), \quad \hat{Y}^* = \frac{1+\theta}{2}\hat{M}^* + \frac{1-\theta}{2}\hat{M} + O\left(\epsilon^2\right) \tag{67}$$

The important point to note from these expressions is that monetary policy now has international spillover effects on the realised values of output. Monetary policy has a larger effect on the exchange

[17] Asset prices depend only on the expected value of variables and, as already noted, the expected value of the log-deviation of any variable is zero to a first order approximation.

rate than in the autarky case so the expenditure switching effect outweighs the effect of monetary policy on aggregate world consumption. Thus an increase in the home money supply causes an expansion of home output and a contraction of foreign output (and vice versa for an expansion of the foreign money supply).

Coordinated Policy

Because the solutions for first moments are identical to the autarky case it follows that the world welfare function is again given by (49). λ_Y and λ_P are also again given by (50). The only differences compared to the autarky case arise because now (the log-deviations of) realised consumption levels are identical (see (65)) and the exchange rate is given by (66) and output levels are given by (67).

It is simple to see that (65) implies that $\lambda_Y = 0$. So the incentive to use monetary policy to stabilise relative consumption levels that arose in the autarky case is no longer relevant. Coordinated monetary policy therefore generates more exchange rate volatility than in the autarky case.

The coordinated equilibrium results in the following choices of feedback parameters

$$\delta_K^C = \delta_{K^*}^{*C} = -1 \tag{68}$$

$$\delta_{K^*}^C = \delta_K^{*C} = 0 \tag{69}$$

The level of world welfare yielded by coordinated policy is

$$\tilde{\Omega}_{RAP}^C = \frac{(\theta - 1)}{4}(1 - \upsilon)\sigma_K^2 \tag{70}$$

where the subscript 'RAP' indicates 'risk sharing after policy'.

Non-Coordinated Policy

Now consider non-coordinated policy. As before, non-coordinated policy can be analysed by considering the relative welfare expression. The fact that the solution for first moments is identical to the autarky case implies that relative welfare is again given by (58). Furthermore, using (33) and (67) it is simple to show that λ_{P_H} and $\lambda_{P_F^*}$ are given by

$$\lambda_{P_H} = \frac{1}{2}E\left[(\hat{K} + \hat{Y})^2 - \frac{(\theta - 1)^2}{4}(\hat{M} - \hat{M}^*)^2\right] \tag{71}$$

$$\lambda_{P_F^*} = \frac{1}{2}E\left[(\hat{K}^* + \hat{Y}^*)^2 - \frac{(\theta - 1)^2}{4}(\hat{M} - \hat{M}^*)^2\right] \tag{72}$$

so

$$E\left[\hat{\tau}\right] = \frac{\lambda_{P_H} - \lambda_{P_F^*}}{\theta} = \frac{E[(\hat{K} + \hat{Y})^2 - (\hat{K}^* + \hat{Y}^*)^2]}{2\theta} \tag{73}$$

This expression is also identical to the autarky case so the expression for relative welfare is identical to the autarky case.

It therefore follows that the mechanism which generates an incentive to deviate from the coordinated policy in the autarky case also arises here. Thus, when $\theta > 1$, the home policymaker faces an incentive to stabilise $\hat{K} + \hat{Y}$ (relative to the coordinated policy) and the foreign policymaker faces an incentive to stabilise $\hat{K}^* + \hat{Y}^*$ (relative to the coordinated policy).

But now there is an additional incentive to deviate from the coordinated policy. This new effect arises because, as can be seen from (67), monetary policy in one country can be used to affect output in the other country. So the incentive for the home monetary authority to destabilise $\hat{K}^* + \hat{Y}^*$ (and the matching incentive for the foreign monetary authority to destabilise $\hat{K} + \hat{Y}$) which was irrelevant in the autarky case becomes relevant here. These new incentives have an additional distortionary effect on home and foreign monetary policy which does not arise in the autarky case.

It will become apparent below that this new distortionary effect can have a non-trivial impact on the welfare gains from coordination. It is therefore important to consider its explanation in more detail. Recall that the coordinated policymaker faces two offsetting incentives with respect to the volatility of work effort in the two countries. On the one hand there is an incentive to stabilise the disutility of work effort which operates through the quadratic terms in $\hat{K}+\hat{Y}$ and $\hat{K}^{*}+\hat{Y}^{*}$ in the world welfare expression. On the other hand there is an incentive to increase the volatility of the disutility of work effort which arises from the incentive to exploit the substitutability of goods (when $\theta > 1$) by shifting demand to the country which has the most favourable supply shock. Coordinated policy is a compromise between these two offsetting incentives. A non-coordinated policymaker, however, clearly does not share the coordinated policymaker's incentive to stabilise the disutility of work effort in the other country. A non-coordinated policymaker will therefore adopt a monetary rule which results in higher volatility of the disutility of work effort in the other county (relative to the coordinated policy).[18]

It is possible to show that the non-coordinated equilibrium now results in the following choice of policy feedback parameters

$$\delta_{K}^{N}=\delta_{K^{*}}^{*N}=\frac{1-3\theta^{2}}{-2\theta\left(1-2\theta\right)} \tag{74}$$

$$\delta_{K^{*}}^{N}=\delta_{K}^{*N}=\frac{1-2\theta+\theta^{2}}{2\theta\left(1-2\theta\right)} \tag{75}$$

and the level of world welfare yielded by non-coordinated policy is

$$\tilde{\Omega}_{RAP}^{N}=\frac{\left(-1+3\theta-\theta^{2}-4\theta^{3}+3\theta^{4}\right)}{4\theta\left(1-2\theta\right)^{2}}(1-\upsilon)\sigma_{K}^{2} \tag{76}$$

Welfare Effects of Coordination

The following proposition can now be stated (and again the proof is omitted).

Proposition 2 *If $\upsilon < 1$ and $\theta \neq 1$ then $\tilde{\Omega}_{RAP}^{C} > \tilde{\Omega}_{RAP}^{N}$, i.e. there are welfare gains from coordination.*

The quantitative implications for the gains from coordination are illustrated in Table 2. The parameter values are the same as those used to construct Table 1 and the structure of the table is identical.[19] It is apparent from Table 2 that the gains from coordination are much larger than in the autarky case in both absolute and relative terms. For instance when $\theta = 6$ the gains from coordination are worth 0.2 percent of equilibrium consumption which represents 12.3 percent of the gains from optimal stabilisation. These figures can not be described as large, but they are also not trivial. These results show that the extra spillover effect embodied in equation (67) (i.e. the link between monetary policy in one country and output in the other country) which is generated by the presence of international financial markets can create non-trivial welfare gains from policy coordination.[20]

[18] Again note that the analysis focuses on the case where $\theta > 1$. When $\theta < 1$ the mechanisms just described are reversed so that non-coordinated policymakers have an incentive to reduce the volatility of the disutility of foreign work effort.

[19] Again, as a point of reference, it is useful to consider an inactive policy regime. The welfare level yielded by this regime is $\tilde{\Omega}_{RAP}^{M}=-\sigma_{K}^{2}/2$.

[20] Notice from (70) and (76) that the size of the welfare effects is proportional to the aggregate variance of the shocks. In a more general model, with more sources of shocks and some persistence in the shock processes, the size of the welfare effects will depend on some aggregate of all shock variances and the degree of persistence of the shocks. This may generate larger welfare effects than reported here.

θ	1	2	4	6
$\tilde{\Omega}^C_{RAP} - \tilde{\Omega}^M_{RAP}$	0.500	0.750	1.250	1.750
$\tilde{\Omega}^N_{RAP} - \tilde{\Omega}^M_{RAP}$	0.500	0.736	1.147	1.535
$\tilde{\Omega}^C_{RAP} - \tilde{\Omega}^N_{RAP}$	0.000	0.014	0.103	0.215
$\frac{100 \times \left(\tilde{\Omega}^C_{RAP} - \tilde{\Omega}^N_{RAP}\right)}{\left(\tilde{\Omega}^C_{RAP} - \tilde{\Omega}^M_{RAP}\right)}$	0.0	1.8	8.3	12.3

Table 2: The welfare effects of coordination: Risk sharing - asset trade after monetary policy

6.3 Asset Trade Before Monetary Policy

Now consider the case where asset trade takes place before monetary policy rules are determined. It will become apparent that this greatly increases the potential sources of international spillover effects of policy because now policymakers believe that their populations are more fully insured against the negative effects of monetary policy.

First Moments

The procedure for obtaining solutions for first moments is identical to the previous cases. Recall that the asset market equilibrium in this case implies $q_H = q_F$ and thus $C = C^*$. Thus the condition that $E[C] = E[C^*]$ replaces the current account balance condition which was relevant in the autarky case and equation (64) which was relevant in the case where asset trade takes place after policy rules are chosen. Combining this new equation with the other equations of the model yields the following expressions for the first moments of C, C^*, Y and Y^*

$$E[\hat{C}] = E[\hat{C}^*] = -\frac{1}{2}\left(\lambda_{P_H} + \lambda_{P_F^*}\right) - \lambda_P \tag{77}$$

$$E[\hat{Y}] = E[\hat{C}] + \lambda_Y + \theta\lambda_P - \frac{\theta}{2}E[\hat{\tau}] \tag{78}$$

$$E[\hat{Y}^*] = E[\hat{C}] + \lambda_Y + \theta\lambda_P + \frac{\theta}{2}E[\hat{\tau}] \tag{79}$$

where

$$E[\hat{\tau}] = \lambda_{P_H} - \lambda_{P_F^*} \tag{80}$$

Realised Values

Regardless of the timing of asset trade the (first-order approximated) realised values of consumption in the two countries are related by (65). The solutions for realised values of the exchange rate and output levels are therefore identical to the asset-trade-after-policy case.

Coordinated Policy

Using the solutions for first moments given in (77) to (79) it is simple to show that the first-order terms in world welfare are identical to the asset-trade-after-policy case. Thus the world aggregate welfare function is again given by (49). Given that both the world welfare function and the behaviour of realised values are identical to the asset-trade-after-policy case it therefore follows that coordinated policy is given by (68) and (69) and the level of welfare yielded by coordinated policy is given by (70).

Non-Coordinated Policy

Non-coordinated policy can again be understood by considering the relative welfare expression. Using the solutions for first moments given in (77) to (79) it is simple to show that the first-order terms in relative welfare are given by

$$(\hat{C} - \hat{C}^*) - (\hat{Y} - \hat{Y}^*) = \theta E[\hat{\tau}] = \theta \left(\lambda_{P_H} - \lambda_{P_F^*}\right) \tag{81}$$

This should be compared with the expression given in (57) which was relevant for both the autarky case and the asset-trade-after-policy case. The expression for first-order terms given in (81) highlights the new source of gains from policy coordination which arises when asset trade takes place before policy rules are chosen. It is immediately apparent from (81) that the welfare effect of changes in λ_{P_H} and $\lambda_{P_F^*}$ is now increasing in θ, while (57) shows that, in the previous cases, the opposite was true.

This can be explained as follows. In both the autarky case and the asset-trade-after-policy case the ability of a country to raise its expected consumption and lower its expected work effort is constrained.[21] A country can therefore only raise consumption and lower work effort by improving its terms of trade (which depends on $\lambda_{P_H} - \lambda_{P_F^*}$). This raises the value of output and reduces the cost of consumption. However an improvement in the terms of trade also reduces demand for a country's output and this quantity effect can (partially or completely) offset the price effect. The extent to which the quantity effect offsets the price effect depends on the elasticity of demand for exports (which is given by θ). The larger is θ, the larger is the quantity effect of an improvement in the terms of trade and the more difficult it becomes for a country to raise the value of income and reduce work effort. The welfare effects of λ_{P_H} and $\lambda_{P_F^*}$ therefore decline as θ increases.

On the other hand, in the case under consideration here, the risk-sharing arrangement implies that the value of output is no longer a constraint on the level of consumption. In this case the quantity effect of an improved terms of trade becomes a welfare benefit. The stronger the quantity effect (i.e. the larger is θ), the more an improvement in the terms of trade reduces work effort and improves welfare. This has no negative consequence for consumption because risk sharing protects the country's consumption level. The welfare effects of λ_{P_H} and $\lambda_{P_F^*}$ therefore increase as θ increases.

Apart from the new expression for the first-order terms in welfare all other components of the non-coordinated policy problem are the same as the asset-trade-after-policy case. The expressions for λ_{P_H} and $\lambda_{P_F^*}$ given in (71) and (72) continue to apply, thus the first-order terms in the relative welfare expression are given by

$$E[(\hat{C} - \hat{C}^*) - (\hat{Y} - \hat{Y}^*)] = \theta \left(\lambda_{P_H} - \lambda_{P_F^*}\right) = \theta E[(\hat{K} + \hat{Y})^2 - (\hat{K}^* + \hat{Y}^*)^2] \tag{82}$$

This expression shows that there are two important contrasts between the asset-trade-before-policy case and the previous two cases. The first contrast concerns the sign of the incentives facing Nash policymakers. In the previous cases, when $\theta > 1$, the home policymaker had an incentive to *reduce* volatility of $\hat{K} + \hat{Y}$ and *increase* the volatility $\hat{K}^* + \hat{Y}^*$ (and vice versa for the foreign policymaker). But in this case (when $\theta > 1$) the incentives are reversed, i.e. the home policymaker has an incentive *increase* the volatility of $\hat{K} + \hat{Y}$ and *reduce* the volatility $\hat{K}^* + \hat{Y}^*$ (and vice versa for the foreign policymaker). The second contrast with the previous cases concerns the impact of increasing θ. In the previous cases a larger value of θ tends to reduce the importance of the first-order terms in welfare. But in the current case a larger value of θ tends to increase the importance of the first-order terms. This implies that a larger value of θ strengthens the incentive for the home policymaker to increase the volatility of $\hat{K} + \hat{Y}$ and reduce the volatility $\hat{K}^* + \hat{Y}^*$ and strengthens the incentive for the foreign policymaker to increase the volatility of $\hat{K}^* + \hat{Y}^*$ and

[21] In the autarky case the constraint is current account balance and the asset-trade-after-policy case the constraint is (64) (which is equivalent to expected current account balance when $\rho = 1$).

θ	1	1.25	1.5	1.75
$\tilde{\Omega}^{C}_{RBP} - \tilde{\Omega}^{M}_{RBP}$	0.500	0.562	0.625	0.688
$\tilde{\Omega}^{N}_{RBP} - \tilde{\Omega}^{M}_{RBP}$	0.500	0.561	0.583	-0.036
$\tilde{\Omega}^{C}_{RBP} - \tilde{\Omega}^{N}_{RBP}$	0.000	0.001	0.042	0.723
$\frac{100\times\left(\tilde{\Omega}^{C}_{RBP} - \tilde{\Omega}^{N}_{RBP}\right)}{\left(\tilde{\Omega}^{C}_{RBP} - \tilde{\Omega}^{M}_{RBP}\right)}$	0.0	0.025	6.7	105.2

Table 3: The welfare effects of coordination: Risk-sharing - asset trade before monetary policy

reduce the volatility $\hat{K} + \hat{Y}$. It will become apparent below that these incentives can become very powerful even for quite moderate values of θ.[22]

It can be shown that the non-coordinated equilibrium results in the following choice of policy feedback parameters

$$\delta^{N}_{K} = \delta^{*N}_{K^*} = \frac{1 + 2\theta - \theta^2}{2\theta(\theta - 2)} \tag{83}$$

$$\delta^{N}_{K^*} = \delta^{*N}_{K} = -\frac{(\theta - 1)^2}{2\theta(\theta - 2)} \tag{84}$$

The welfare yielded by non-coordinated policy is

$$\tilde{\Omega}^{N}_{RBP} = -\frac{1 - 2\theta^2 + \theta^3}{4\theta(\theta - 2)^2}(1 - \upsilon)\sigma^2_K \tag{85}$$

where the subscript 'RBP' indicates 'risk sharing before policy'.

Welfare Effects of Coordination

As in the previous cases the following proposition can now be stated (and again the proof is omitted).

Proposition 3 *If $\upsilon < 1$ and $\theta \neq 1$ then $\tilde{\Omega}^{C}_{RBP} > \tilde{\Omega}^{N}_{RBP}$, i.e. there are welfare gains from coordination.*

The quantitative implications of the additional spillover effects arising in this case are illustrated in Table 3.[23] It is clear from Table 3 that the gains from coordination can now be very large, both in relative and absolute terms. This reflects the powerful incentives generated by the new spillover effect present in this case. The fact that policymakers now believe that their populations are insured against the choice of policy rules gives a very strong incentive to attempt to shift the burden of production onto the other country. This incentive is increasing in the power of the expenditure switching effect (i.e. in the value of θ). In fact, this incentive can be so powerful that the second-order conditions of non-coordinated policymakers are violated for values of θ greater than approximately 1.78. Valid Nash equilibria therefore only exist for $\theta \lesssim 1.78$.

A comparison between the results in Tables 1, 2 and 3 shows that the welfare gain from policy coordination can be very sensitive to the presence or absence of international financial markets and also to the timing of asset market trade. Moving from the financial-autarky case to the asset-trade-after-policy case creates a link between monetary policy in one country and output in the other country which creates modest (but non-trivial) gains from policy coordination. Moving from the asset-trade-after-policy case to the asset-trade-before-policy case creates a strong incentive for the Nash policymaker to attempt to shift the burden of production onto the other country. This creates potentially large welfare gains from coordination.

[22] Again note that the analysis focuses on the case where $\theta > 1$. The incentives described here also exist $\theta < 1$ but are correspondingly much weaker.

[23] As in previous cases it is useful to consider an inactive policy regime as a point of reference. The welfare level yielded by this regime is $\tilde{\Omega}^{M}_{RBP} = -\sigma^2_K/2$.

		θ	
ρ	1.25	1.5	1.75
0.25	0.168 (12.8)	1.042 (75.8)	6.509 (452.8)
0.5	0.013 (1.5)	0.042 (4.8)	0.080 (8.6)
1	0.001 (0.2)	0.042 (6.7)	0.723 (105.2)
2	0.013 (2.8)	0.167 (33.3)	-
4	0.022 (5.9)	0.260 (59.5)	-

Table 4: The effects of risk aversion on the welfare gains from coordination

		θ	
Φ	1.25	1.5	1.75
1.0	0.001 (0.2)	0.042 (6.7)	0.723 (105.2)
1.1	0.001 (0.2)	0.029 (4.6)	0.369 (53.7)
1.2	0.001 (0.2)	0.021 (3.4)	0.223 (32.5)

Table 5: The effects of the mark-up on the welfare gains from coordination

7 Some Parameter Variations

The analysis so far has focused on the case where the coefficient of relative risk aversion is unity ($\rho = 1$), utility is linear in work effort ($\mu = 1$) and the output subsidy is set at a level which eliminates the monopoly markup ($\Phi = 1$). This section briefly considers the implications of relaxing each of these assumptions. In what follows the explicit derivation is omitted and the discussion focuses on numerical examples. The analysis also only focuses on the case where financial markets exist and asset trade takes place before policy decisions are made.[24] The results reported here show that the large welfare gains identified above are quite robust to variations in ρ (the coefficient of relative risk aversion is unity) and α (the production subsidy) but they are potentially very sensitive to μ (which determines the elasticity of labour supply).

Table 4 reports the welfare gains from policy coordination for a range of values of θ and ρ. For each parameter combination the welfare gain is reported as a percentage of consumption. The bracketed figure in each cell of the table reports the welfare gain as a percentage of the gains from stabilisation. It has previously been shown by Benigno and Benigno (2003a) that the welfare gains from policy coordination are zero when $\rho\theta = 1$. Consistent with this Table 4 shows that the welfare gains from coordination rise as $\rho\theta$ differs from unity in either direction.

Table 5 reports the welfare gains from coordination for a range of values of θ and Φ. Φ is the mark-up net of the production subsidy so higher values of Φ represent lower values of the production subsidy. It is apparent that the welfare gains from coordination decline as Φ rises. This can be understood by considering the welfare expression given in (23). This expression shows that a higher value of the mark-up reduces the weight on the first and second moments of work effort in welfare. All the welfare gains from coordination discussed in the previous section arise from policy interactions related to the volatility of the disutility of work effort. A higher value of the mark-up reduces the importance of work effort in welfare and thus must also reduces the welfare gains from coordination.

Table 6 reports the welfare gains from coordination for a range of values of θ and μ. It can be seen that the welfare gains from policy coordination decline as μ is increased. It is also apparent that the welfare gains are very sensitive to the value of μ (which determines the elasticity of labour supply). The very large welfare gains that arise when $\mu = 1$ fall almost to zero for quite moderate values of $\mu > 1$. The negative effect of μ on the welfare gains can be easily understood by again considering the welfare expression given in (23). A higher value of μ increases the weight on the

[24] The effects of varying ρ, μ and Φ are qualitatively similar in the other cases but are quantitatively smaller.

	θ				
μ	1.25	1.5	1.75	2	4
1.00	0.001 (0.2)	0.042 (6.7)	0.723 (105.2)	-	-
1.25	0.000 (0.1)	0.005 (1.0)	0.025 (4.9)	0.083 (15.6)	-
1.50	0.000 (0.0)	0.001 (0.3)	0.004 (1.0)	0.010 (2.4)	0.083 (16.7)
1.75	0.000 (0.0)	0.000 (0.1)	0.001 (0.4)	0.002 (0.7)	0.011 (2.8)
2.00	0.000 (0.0)	0.000 (0.0)	0.000 (0.2)	0.001 (0.3)	0.003 (0.9)

Table 6: The effects of the elasticity of labour supply on the welfare gains from coordination

second moment of work effort in welfare relative to the first moment term. The large welfare gains from coordination reported in the asset-trade-before-policy case arose because Nash policymakers have a strong incentive to increase the volatility of the disutility of work effort in order shift expected work effort onto the other country. Increasing μ increases the negative welfare effect of work effort volatility and thus reduces the incentive to engage in this form of policy.[25]

Given the sensitivity of the welfare effects to the value of μ it is clearly important to consider the empirically relevant range of values for this parameter. Rotemberg and Woodford (1999) suggest a value of 1.47, while Benigno (2001) suggests a plausible value of μ could be as high as 5. Values of μ in this range clearly significantly reduce the welfare gains from coordination.

8 Conclusion

This paper has analysed the implications of the expenditure switching effect and the structure of financial markets for the existence and size of welfare gains from policy coordination. The expenditure switching effect is parameterised in terms of the elasticity of substitution between home and foreign goods. It is shown that welfare gains to policy coordination can arise when the elasticity differs from unity, but these gains are quantitatively small when there is no international financial market. On the other hand, when there is a sufficiently sophisticated financial market to allow full consumption risk sharing the gains from policy coordination are found to be much larger. This is particularly true when asset trade takes place before monetary policy rules are chosen.

The model is simple enough to yield explicit analytical solutions which make it possible to trace the mechanisms which give rise to gains from coordination. In the financial autarky case, gains from coordination arise because coordinated policy uses monetary policy (*ex post*) to shift production to the country with the most favourable labour supply shock. This raises the expected level of consumption but creates output and exchange rate volatility. Non-coordinated policymakers care more about the volatility of the disutility of work effort of their own populations. Non-coordinated policy therefore produces suboptimally low output volatility. In the asset-trade-after-policy case, asset trade creates a spillover effect which implies that non-coordinated policymakers use monetary policy in an attempt to raise output volatility in the other country. The welfare gains from coordination are therefore greater than in the financial autarky case. The asset-trade-before-policy case introduces a third, and potentially powerful, mechanism. In this case policymakers believe that agents are more fully insured against the income volatility created by monetary policy. Non-coordinated policymakers therefore have a strong incentive to create *excess* output volatility in order to shift the expected burden of production onto the other country. The analysis shows clearly the role of the elasticity of substitution between home and foreign goods. All the mechanisms just described operate when the elasticity of substitution is greater than unity and the spillover effects associated with financial markets become more significant as the elasticity increases.[26]

The results reported in this paper show that the welfare gains from policy coordination can, in

[25] Notice that the range of values of θ for which a valid Nash equilibrium exists increases with μ.

[26] The mechanisms just described do not operate when the elasticity is equal to unity and they operate in reverse when the elasticity is less than unity.

theory, be quite large. The size of these welfare gains are, however, quite sensitive to the structure of financial markets. The empirically relevant magnitude of welfare gains from coordination obviously depends on what is regarded as the empirically relevant financial market structure. Clearly, for developed countries, the financial autarky case is not realistic. Modern international financial markets (though not complete) offer significant scope for risk sharing so the two risk-sharing cases analysed above are likely to be closer to reality.[27] But it is less easy to determine which of the asset-trade-before-policy or the asset-trade-after-policy cases is the more empirically relevant. International financial markets rarely offer explicit insurance against the actions of policymakers but (as is apparent from the examples used in this paper) equity markets implicitly do provide insurance of this form so the asset-trade-before-policy case cannot be dismissed as irrelevant.

The gains from coordination are also found to be sensitive to the elasticity of labour supply. The welfare gains decline quite strongly as labour supply becomes more inelastic and can be almost zero for values of the labour-supply elasticity within the empirically plausible range. It must be emphasised, however, that the model used in this paper is not sufficiently detailed to allow a comprehensive calibration exercise. The model identifies a number of mechanisms which can be very powerful. A proper judgement of their true magnitude can only be gained by considering a richer dynamic model. Pappa (2002) and Tchakarov (2002) provide examples of this type of exercise. Further research in this direction is likely to prove valuable.

Appendix

Portfolio allocation and asset prices

In the following the operator E denotes expectations conditional on information at the time at which asset trade takes place. There are four first-order conditions for the choice of asset holdings. After some rearrangement they imply the following four equations

$$E\left[C^{-\rho}y\right] = E\left[C^{-\rho}\right]q_H, \qquad E\left[C^{-\rho}y^*\right] = E\left[C^{-\rho}\right]q_F \tag{86}$$

$$E\left[C^{*-\rho}y\right] = E\left[C^{*-\rho}\right]q_H, \qquad E\left[C^{*-\rho}y^*\right] = E\left[C^{*-\rho}\right]q_F \tag{87}$$

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

$$C = y + \zeta_H\left(y - q_H\right) + \zeta_F\left(y^* - q_F\right) \tag{88}$$

$$C^* = y^* + \zeta_H^*\left(y - q_H\right) + \zeta_F^*\left(y^* - q_F\right) \tag{89}$$

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 and y^*.

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

$$C = \frac{q_H\left(y + y^*\right)}{q_H + q_F}, \qquad C^* = \frac{q_F\left(y + y^*\right)}{q_H + q_F} \tag{90}$$

and portfolio shares are given by

$$\zeta_H = -\zeta_H^* = -\frac{q_F}{q_H + q_F}, \qquad \zeta_F = -\zeta_F^* = \frac{q_H}{q_H + q_F} \tag{91}$$

[27] Given the incompleteness of real world financial markets, it would be interesting to investigate the welfare gains to coordination in some intermediate financial market structure. A possible example of an intermediate structure is one where financial trade only takes place in the form of non-contingent bonds. This type of model will inevitably involve asset stock dynamics and will therefore require more extensive use of numerical simulation techniques. An alternative way to model an intermediate degree of risk sharing has recently been proposed by Ligon, Thomas and Worrall (2000) and Kehoe and Perri (2000). It may also be interesting to consider the gains from monetary policy coordination in this alternative 'endogenous incomplete market' framework.

Notice that (90) implies

$$\frac{C}{C^*} = \frac{q_H}{q_F} \tag{92}$$

The two asset prices are given by

$$q_H = \frac{E\left[\frac{y}{(y+y^*)^\rho}\right]}{E\left[\frac{1}{(y+y^*)^\rho}\right]}, \qquad q_F = \frac{E\left[\frac{y^*}{(y+y^*)^\rho}\right]}{E\left[\frac{1}{(y+y^*)^\rho}\right]} \tag{93}$$

Thus asset prices depend on expected relative output levels.

Model solution

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

$$A_1 V = A_2 E[V] + A_3 \Lambda + A_4 \xi + O\left(\epsilon^3\right) \tag{94}$$

where V is the vector of endogenous variables of the model, Λ is the vector of second-order terms (i.e. $\lambda_Y,\ \lambda_P,\ \lambda_{P_H}$ etc), $\xi' = \left[\hat{K}\ \hat{K}^*\right]$ and $A_1, A_2,\ A_3$ and A_4 are matrices of coefficients taken from the relevant set of (approximated) equations.

The solution method follows Sutherland (2002a) and can be thought of as consisting of two steps. In the first step expectations are taken of both sides of (94) and the resulting matrix equation is solved for $E[V]$ in terms of $E[\Lambda]$. This yields

$$E[V] = (A_1 - A_2)^{-1} A_3 E[\Lambda] + O\left(\epsilon^3\right) \tag{95}$$

(Note that $E[\xi] = 0$ by assumption.) This solution yields expressions for the first moments of C, C^*, Y and Y^* which are used in the construction of the welfare expression. Notice that these expressions will be in terms of the elements of Λ.

In the second step of the solution process 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

$$A_1 V = A_2 E[V] + A_4 \xi + O\left(\epsilon^2\right) \tag{96}$$

from which is follows that

$$E[V] = 0 + O\left(\epsilon^2\right) \tag{97}$$

and

$$V = A_1^{-1} A_4 \xi + O\left(\epsilon^2\right) \tag{98}$$

so

$$E[VV'] = A_1^{-1} A_4 E[\xi\xi'] (A_1^{-1} A_4)' + O\left(\epsilon^3\right) \tag{99}$$

where

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

The expression for $E[VV']$ given in (99) can be used to construct the elements of $E[\Lambda]$.

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