Common Currencies vs. Monetary Independence*

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Abstract

We study the optimal monetary policy in a two-country open-economy model under two monetary arrangements: (a) multiple currencies controlled by independent policy makers; (b) common currencies with a centralized policy maker.

Our findings suggest that: (i) Monetary policy competition leads to higher long-term inflation and interest rates with large welfare losses; (ii) The inflation bias and the consequent losses are larger when countries are unable to commit to future policies; (iii) the welfare losses from higher long-term inflation dominates the welfare costs of losing the ability to react optimally to shocks. Therefore, the coordination of policies implicit in the adoption of a common currency has positive welfare consequences.

JEL classification: E, E5, F. *Keywords*: Optimal monetary policy, international coordination, common currency.

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Introduction

The study of monetary policy interaction in open economies has a long tradition in international economics. Persson & Tabellini (1995) provide an overview of the main results obtained in this literature. Some of these results lead to the view that monetary policy coordination is preferable to policy competition while other contributions, such as Rogoff (1985), conclude that policy competition is preferable to coordination. In this paper we reconsider the consequences of using a common currency as a way to achieve monetary policy coordination but in a model in which the objective of the policy makers coincides with the agents' welfare. We are interested in the following questions. First, does monetary policy competition lead to systematic inflation biases with significant welfare consequences? Second, is this bias affected by the ability to commit to future policies? Third, abstracting from systematic inflationary biases, is the loss of the ability to react optimally to shocks quantitatively important in terms of welfare?

We address these questions in the context of a simple two-country open economy model where countries are technologically integrated. The production activity in each country requires two inputs: one is domestically produced and the other imported from abroad. The purchase of the intermediate inputs must be financed in advance and the nominal interest rate has a distortionary effect (cost channel of monetary transmission). In a closed economy, where both inputs are produced domestically, the optimal monetary policy would keep the nominal interest rate at the lowest level, zero, consistent with the Friedman rule. In an open economy, however, monetary policy also affects the terms of trade. Specifically, an increase in the interest rate induces an appreciation of the real exchange rate that, controlling for the direct cost effect of the interest rate, generates an expansion in the domestic activity. The impact of monetary policy on the terms of trade generates a conflict of interest between the two countries which is the basis of their strategic interaction. This conflict is also present in other open economy models such as Corsetti & Pesenti (2001b) and Corsetti, Pesenti, Roubini, & Tille (2000). In our model, however, this policy competition generates an inflationary bias with sizable adverse welfare consequences.

A second result of the paper is that the inflationary bias created by policy competition is magnified by the lack of policy commitment. We show that when countries are unable to commit to future policies, competition leads to higher inflation, higher interest rates and lower welfare. The key element that generates this result is the assumption of a difference between the short-term and the long-term elasticity of substitution between domestic and foreign inputs. Because firms find it more difficult to readjust their input composition in the short-term, changes in the current interest rates will have a larger impact on the terms of trade than future changes. This implies that, when the policy makers commit to future policies, they understand that the interest rates they choose today for the future will not have a large impact on the real exchange rate: the negative cost effect becomes more important than the positive terms of trade effect and the monetary authorities will have less incentive to choose higher interest rates. In future periods, however, when firms become inflexible, the monetary authorities will have an incentive to change the pre-set interest rates. This implies that the time-consistent policies will generate higher long-term interest and inflation rates. Because this inflation bias will be eliminated when countries coordinate their policies, the currency unification solves both the problems of policy coordination and commitment.

This theoretical result finds empirical support in the experience of the European countries. As the recent history of the "European Monetary System" and the subsequent experience of the "European Monetary Union" have shown, the increasing monetary integration of Europe has been accompanied by falling and convergent inflation and interest rates as shown in Figure 1.

Figure 1: Inflation and interest rates in the EMU countries, 1979-2000

In addition to studying the implications of a common currency for inflation and welfare in the long-run, we also evaluate the welfare costs of losing the short-term ability to react optimally to internal and external shocks (cyclical independence). We find that the cost of losing cyclical monetary policy independence is extremely small, almost insignificant. Importantly, neither this finding nor the estimated welfare gains associated with inflation reduction in the long-run depend on the weights given by the policy maker to the welfare of the two countries. Therefore, abstracting from the redistributional effects through seigniorage, the creation of a currency union and the unilateral adoption of a foreign currency are equivalent in the sense of leading to the same long-term inflation reduction and to similar cyclical policies.

Most of the recent literature on international monetary policy coordination has used variations of the "new open economy macroeconomic models" (Obstefeld & Rogoff (2000b)). Examples are Benigno & Benigno (2001), Corsetti & Pesenti (2001a), Obstefeld & Rogoff (2000a) and Pappa (2000). These papers focus on the strategic interaction that derives from optimal response to shocks (policy stabilization) and devote little attention to the problem of systematic inflationary biases, which is central for our results. They conclude that either the allocation with coordinated policies does not differ from the allocation with independent policies, or the gains from coordination are small. One exception is Canzoneri, Cumby, & Diba (2001). Overall, however, the conclusion of these recent contributions is that international monetary policy coordination leads to modest or zero gains.

Earlier work by Rogoff (1985) does focus on systematic inflationary bias arising from strategic interaction but reaches a completely different conclusion from ours. He concludes that, abstracting from the gains of policy stabilization, coordination may lead to higher inflation and lower welfare. The same conclusion is also likely to follow from many of the new open economy macroeconomic models with discretionary policies (no commitment). The intuition is simple. In a coordinated equilibrium the distortions induced by monopolistic competition create an incentive for the monetary authorities to inflate. When policies are chosen competitively, however, this incentive is mitigated by the negative impact of inflation on the terms of trade. Therefore, assuming that an equilibrium exists, policy competition can lead to lower inflation and higher welfare.

Our model differs from the new open economy macroeconomic models in three dimensions. First, we do not assume that producers operate in monopolistic competitive markets and production is inefficient. A second difference is that money does not enter the utility function but is held for transactions purposes. By further assuming limited participation in financial markets, monetary policy interventions have liquidity effects similar to the open economy models of Grilli & Roubini (1992) and Schlagenhauf & Wrase (1995). The third difference is that prices are perfectly flexible. Thus, the channel through which a monetary expansion affects the real sector of the economy is not by increasing the nominal aggregate demand but through the reduction in the financing cost of firms. These modeling features generate the different results described above.

Finally we emphasize that in our model the time-consistency problem disappears after the adoption of a common currency. Recent contributions such as Chari & Kehoe (2002), Cooper & Kempf (2001) and Uhlig (2002) emphasize that the time consistency problem of monetary policy may still arise in a monetary union if fiscal policies are not coordinated. In this case the full gains from monetary unification are obtained only if the monetary authority is able to commit to future policies or there are restrictions to the fiscal autonomy of the individual countries or regions.

Plan of the paper

To facilitate the understanding of the theoretical framework, we introduce the model in stages. Section I presents the simplest version in which there is only one period and decisions are static. This simplified framework illustrates how "policy competition" leads to an inflation bias and reduces welfare. Section II makes the model dynamic by adding a second period. This allows us to distinguish the short-run and long-run elasticity of substitution between domestic and foreign inputs, and to differentiate the case of "policy commitment" from the case of "policy discretion". After showing the problems of policy coordination and commitment in the two period-model, Section III generalizes the analysis to an infinite horizon setting and specifies the whole monetary sector. For economy of space the technical analysis of the infinite horizon model is provided in a supplemental appendix available in electronic form at the journal web site. In this appendix we also study the model with international mobility of capital. The quantitative properties of the general model are studied in Section IV.

I One-period model: the coordination problem

Households: There are two symmetric countries populated by a continuum of households and a continuum of firms. For simplicity we assume that the mass of households, normalized to 1, is equal to the mass of firms. Therefore, each firm employs one household-worker. Households supply their labor services inelastically and consume the surplus generated by the firm. The utility is $U(c)$ and satisfies the standard properties. Because firms are owned by the households, the division of the surplus between wages and profits is irrelevant.

Firms and technology: The main action comes from the decisions of firms. Firms produce output with two intermediate inputs: a domestically produced input and an imported input. In country 1 the production technology is:

$$y_1 = A_1 x_1^{\nu} \qquad x_1 = \left(x_{11}^{\epsilon} + \phi \cdot x_{12}^{\epsilon}\right)^{\frac{1}{\epsilon}} \tag{1}$$

where A_1 is the technology level of country 1 and x_1 is a composite input. The composite input aggregates the intermediate input produced domestically, x_{11}, and the input produced abroad, x_{12} (imports). Throughout the paper we will use the first subscript to denote the country that uses the input and the second subscript for the country that produces the input. Notice that the intermediate inputs are used in production in the same period in which they are produced.[1] The same production function, with technology level A_2, is used by firms in country 2. We assume that $\nu < 1$ and $\epsilon < \nu$.

Firm financing and monetary policy: Firms finance the purchase of the intermediate inputs by borrowing from a financial intermediary. The nominal interest rates on loans are R_1 and R_2. Denote by e the nominal exchange rate (units of currency of country 1 to purchase one unit of currency of country 2). The real exchange rate is denoted by $\bar{e} = eP_2/P_1$, where P_1 and P_2 are the nominal prices in the two countries (both expressed in their respective currencies). Because the price of the final goods must be equal to the price of the intermediate goods produced at home, the loan contracted by a firm in country 1 is equal to $P_1 x_{11} + eP_2 x_{12} = P_1(x_{11} + \bar{e} x_{12})$ and the loan contracted by a firm in country 2 is $P_2 x_{22} + P_1 x_{21}/e = P_2(x_{22} + x_{21}/\bar{e})$.

The monetary authorities of the two countries maximize their own country's welfare by choosing the nominal interest rates strategically according to a Nash scheme of policy competition. In this simplified version of the model it is not necessary to specify the whole monetary sector because all the relevant problems can be expressed as functions of the real variables and the interest rates. The full specification of the monetary sector will be provided in Section III when we consider the infinite horizon model.

[1] This should be considered an approximation to the model in which the intermediate inputs are purchased in the previous period. This alternative assumption does not change the properties of the model but would make the analysis more complex.

I.1 The firm's problem and general equilibrium for given interest rates

Let's start by taking as given the interest rates chosen by the two countries. After solving for the general equilibrium for given R_1 and R_2, we will determine the interest rates as the solution to the policy game played by the monetary authorities. The optimization problem solved by a firm in country 1 is:

$$\max_{x_{11},x_{12}} \left\{ P_1 \left[A_1 \Big(x_{11}^{\epsilon} + \phi x_{12}^{\epsilon} \Big)^{\frac{\nu}{\epsilon}} - (x_{11} + \bar{e} \cdot x_{12})(1 + R_1) \right] \right\} \tag{2}$$

The solution to the firm's problem is:

$$x_{11} = \left(\frac{\nu A_1}{1 + R_1} \right)^{\frac{1}{1-\nu}} \left[1 + \phi \left(\frac{\phi}{\bar{e}} \right)^{\frac{\epsilon}{1-\epsilon}} \right]^{\frac{\nu-\epsilon}{\epsilon(1-\nu)}} \tag{3}$$

$$x_{12} = \left(\frac{\phi}{\bar{e}} \right)^{\frac{1}{1-\epsilon}} x_{11} \tag{4}$$

Equations (3) and (4) are the demands for the domestic and foreign inputs. These inputs depend positively on the level of technology and negatively on the domestic interest rate. Moreover, if $\epsilon < \nu$, as we assume, a lower value of $\bar{e}$ has a positive impact on both inputs. Therefore, a policy that induces an appreciation of the real exchange rate—that is, a fall in $\bar{e}$—might have an expansionary effect. The firm's solution in country 2 is also given by (3) and (4) but with A_2, R_2 and $1/\bar{e}$ replacing A_1, R_1 and $\bar{e}$.

The general equilibrium is derived by imposing market clearing conditions in the goods markets and the foreign exchange market. In the goods markets we have:[2]

$$Y_1 = C_1 + X_{11} + X_{21} \tag{5}$$

$$Y_2 = C_2 + X_{22} + X_{12} \tag{6}$$

The gross production (Y_1 or Y_2) must be equal to the demand for domestic consumption, (C_1 or C_2), and the demand for intermediate inputs from domestic firms, (X_{11} or X_{22}), and foreign firms, (X_{21} or X_{12}).

For the moment we assume that there is not international mobility of financial assets and the trade account must always balance, that is, $eP_2X_{12} = P_1X_{21}$. Dividing both sides by P_1, the equilibrium condition in the exchange rate market is:

$$\bar{e} \cdot X_{12} = X_{21} \tag{7}$$

The case with international financial transactions is studied in the supplemental appendix available at the journal web site.

[2] We use capital letters to denote aggregate variables and prices, and lowercase letters to denote individual variables. The only exception is the exchange rate that we denote by e to distinguish it from the expectation operator E.

Conditions (5), (6) and (7), together with the demands for the intermediate inputs (3) and (4), define the general equilibrium. Notice that these conditions do not depend on the nominal prices. Therefore, in the determination of the equilibrium we can ignore the full specification of the monetary sector once we know the two nominal interest rates. Using these conditions, Appendix A derives the following equations:

$$C_1 = \left(\frac{\nu A_1}{1+R_1}\right)^{\frac{1}{1-\nu}} \left(\frac{1+R_1-\nu}{\nu}\right) \left[1 + \phi\left(\frac{\phi}{\bar{e}}\right)^{\frac{\epsilon}{1-\epsilon}}\right]^{\frac{\nu(1-\epsilon)}{\epsilon(1-\nu)}} \tag{8}$$

$$C_2 = \left(\frac{\nu A_2}{1+R_2}\right)^{\frac{1}{1-\nu}} \left(\frac{1+R_2-\nu}{\nu}\right) \left[1 + \phi\left(\phi\bar{e}\right)^{\frac{\epsilon}{1-\epsilon}}\right]^{\frac{\nu(1-\epsilon)}{\epsilon(1-\nu)}} \tag{9}$$

$$\left[\frac{A_1(1+R_2)}{A_2(1+R_1)}\right]^{\frac{1}{1-\nu}} = \bar{e}^{\frac{1+\epsilon}{1-\epsilon}} \left[\frac{1+\phi(\phi\bar{e})^{\frac{\epsilon}{1-\epsilon}}}{1+\phi\left(\frac{\phi}{\bar{e}}\right)^{\frac{\epsilon}{1-\epsilon}}}\right]^{\frac{\nu-\epsilon}{\epsilon(1-\nu)}} \tag{10}$$

Equations (8) and (9) define the net production and consumption in country 1 and 2 respectively, and equation (10) defines the equilibrium in the exchange rate market. These three equations characterize the general equilibrium for given interest rates R_1 and R_2. To understand the welfare impact of the interest rates, it will be convenient to emphasize the following properties of the equilibrium.

(a) **Financing cost effect**: Keeping constant the terms of trade ($1/\bar{e}$ for country 1 and $\bar{e}$ for country 2), an increase in the domestic interest rate decreases domestic consumption.

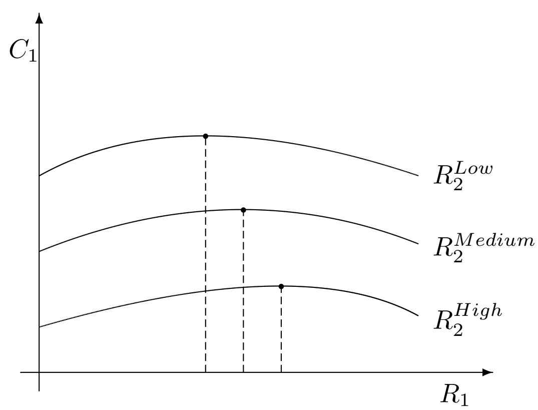
(b) **Terms of trade effect**: Keeping constant the other country's interest rate, an increase in the domestic interest rate improves the terms of trade. Moreover, keeping constant the domestic interest rate, an improvement in the terms of trade increases consumption.

These are the two channels through which the interest rates affect production and consumption. As can be seen from equations (3) and (4), if we keep the real exchange rate constant, an interest rate increase reduces the intermediate inputs, which in turn reduces production and consumption. This is because the intermediate inputs must be financed in advance and a higher interest rate increases the cost of financing these inputs. This is the cost channel of monetary policy.

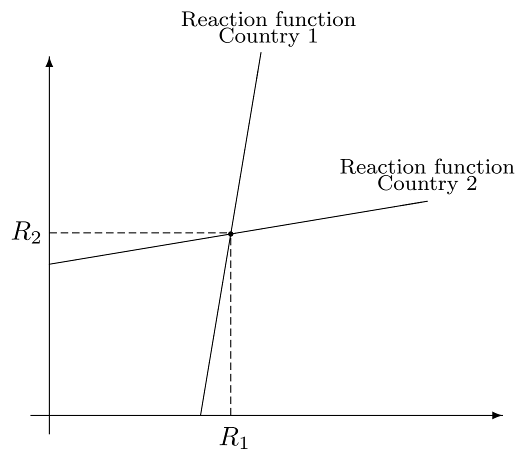
If we were in a closed economy and both inputs were produced domestically, the direct cost channel would be the only mechanism through which the nominal interest rate affects the real sector of the economy. In this case the optimal policy would set a zero nominal interest rate (Friedman rule). With trade, however, there is an additional channel which works through the terms of trade. It can be verified from equation (10) that a higher value of R_1 must be associated with a lower value of $\bar{e}$ or better terms of trade for country 1. The lower value of $\bar{e}$ reduces the cost of the foreign input and increases the demand of both inputs. This can be clearly seen from equations (3) and

(4) if we keep the interest rate constant. Therefore, ignoring the direct impact of the interest rate, the improvement in the terms of trade increases consumption.

The total effect of an interest rate increase depends on whether the direct cost effect dominates the terms of trade effect. It turns out that the terms of trade effect is larger when the interest rate is low and smaller when the interest rate is high. Therefore, consumption is first increasing and then decreasing as shown in the first panel of Figure 2. This panel plots the level of consumption for country 1 as a function of its interest rate for given values of the interest rate in country 2.[3]



(a) Country's objective



(b) Reaction functions

Figure 2: Countries' objective and Nash equilibrium.

I.2 Nash policy equilibrium in the one-period model

If we assume that the two countries set their interest rates competitively according to a Nash strategic scheme, then the maximizing value of R_1 constitutes a point in the reaction function of country 1 to the interest rate of country 2. By determining the optimal R_1 for each value of R_2, we construct the whole reaction function. The intersection of the two countries reaction functions determines the Nash equilibrium as shown in the second panel of Figure 2.

The competitive interaction leads to positive interest rates in both countries. In the symmetric case, that is, $A_1 = A_2$, this reduces the welfare of both countries. In fact, the real exchange rate will be 1 in equilibrium and only the negative financing cost effect of the interest rate operates. As we will show later, in the case of asymmetric countries the welfare of one country could increase. However, the net welfare consequences, that is the sum for the two countries, are always negative.

[3]After fixing R_1 and R_2, the value of C_1 is determined by the solutions of equations (8) and (10).

The parameter ϵ plays a key role in determining the equilibrium interest rates. As we reduce the value of ϵ, that is, we increase the degree of complementarity between domestic and foreign imports, the reaction function of country 1 moves to the right and the reaction function of country 2 moves up. Therefore, the equilibrium will be characterized by higher nominal interest rates. In a world where long term interest rates are determined by the Fisher rule, the higher nominal interest rates will be associated with higher inflation rates. The link between the nominal interest rate and the inflation rate will be made precise when we describe the infinite horizon model in Section III.

For illustrative purposes, we show here the consequences of monetary policy competition with a numerical example. We set $A_1 = A_2 = 1$, $\nu = 0.9$ and consider alternative values of the elasticity of substitution between domestic and foreign inputs, that is, $1/(1-\epsilon)$. Given the value of ϵ we then choose ϕ so that the imports of each country is 25 percent the value of net domestic output. As shown in Table 1, the equilibrium interest rates and the welfare losses are significant and they increase as we reduce the degree of substitutability between domestic and foreign inputs.

Table 1: Equilibrium interest rates and consumption losses from policy competition.

	Elasticity=1.6	Elasticity=1.1	Elasticity=0.7
Interest rate	5.31	9.67	24.40
Consumption loss	0.70	2.12	10.57

We summarize the main result of the one-period model as follows:

Result 1 (Competition and inflation bias) *Policy competition leads to higher interest (and inflation) rates than policy cooperation. The higher the complementarity between domestic and foreign inputs, the higher is the bias.*

II A two-period model: the commitment problem

Because of the static nature of the model developed in the previous section, there are no time-consistency issues in the choice of policies. In order to illustrate how policy commitment affects the equilibrium outcome, we extend the previous analysis in two ways. First, we add a second period. Second, we distinguish between the short-term and the long-term elasticity of substitution between domestic and foreign inputs.

Households: The characteristics of the household sector do not change. Although now there are two periods, households do not take any action in the first period. They supply labor and consume only in the second period.

Firms and technology: As in the previous model, firms produce output with the two intermediate inputs. However, we now assume that the short term elasticity of substitution between these two inputs differs from the long term elasticity. As emphasized in empirical studies of international trade (see, for example, Gallaway, McDaniel, & Rivera (2000)), the elasticity of substitution between domestically produced goods and foreign imports increases with the length of the period. To capture this idea, we assume that the production plan of the firm takes place in two stages. In the first period the firm chooses the optimal plan according to the long-term technology. In the second period then it considers the possibility of changing the original plan. At this stage, however, the technology is characterized by a lower degree of substitutability between inputs. The modeling idea is similar to the putty-clay model of Atkeson & Kehoe (1999).

Consider a firm in country 1. The long-term technology faced in the first period is:

$$y_1 = A_1 x_1^{\nu} \qquad\qquad x_1 = \Big(x_{11}^{\epsilon} + \phi \cdot x_{12}^{\epsilon}\Big)^{\frac{1}{\epsilon}} \tag{11}$$

Denote by $(\hat{x}_{11}, \hat{x}_{12})$ the plan chosen in the first period. This can be interpreted as the choice of a production technique. The actual purchase of the inputs will take place in the second period. At this stage the firm can change the input composition. However, the technology available to the firm after the commitment to the plan $(\hat{x}_{11}, \hat{x}_{12})$ is:

$$y_1 = A_1 x_1^{\nu} \qquad\qquad x_1 = \lambda(\hat{x}_{11}, \hat{x}_{12}) \cdot \Big(x_{11}^{\eta} + \omega(\hat{x}_{11}, \hat{x}_{12}) \cdot x_{12}^{\eta}\Big)^{\frac{1}{\eta}} \tag{12}$$

where $\eta < \epsilon$ and the parameters λ and ω are functions of the previously chosen plan $(\hat{x}_{11}, \hat{x}_{12})$. At this stage the firm chooses x_{11} and x_{12} but cannot change $\hat{x}_{11}$ and $\hat{x}_{12}$. We refer to (11) as the "long-term technology" and to (12) as the "short-term technology".

The condition $\eta < \epsilon$ captures the idea that the elasticity of substitution between the domestic and the foreign inputs is smaller in the short-term. The parameters $\lambda(\hat{x}_{11}, \hat{x}_{12})$ and $\omega(\hat{x}_{11}, \hat{x}_{12})$ are determined by imposing two conditions. First, if the firm does not change the original plan, it will produce the same goods planned in advance, that is:

$$\Big(\hat{x}_{11}^{\epsilon} + \phi \cdot \hat{x}_{12}^{\epsilon}\Big)^{\frac{1}{\epsilon}} = \lambda \cdot \Big(\hat{x}_{11}^{\eta} + \omega \cdot \hat{x}_{12}^{\eta}\Big)^{\frac{1}{\eta}} \tag{13}$$

The second condition is that the marginal rates of substitution are the same in the short-term and in the long-term when evaluated at the original plan, that is:

$$\phi \cdot \left(\frac{\hat{x}_{12}}{\hat{x}_{11}}\right)^{\epsilon-1} = \omega \cdot \left(\frac{\hat{x}_{12}}{\hat{x}_{11}}\right)^{\eta-1} \tag{14}$$

Denote by $\kappa_1 = (\hat{x}_{12}/\hat{x}_{11})$ the ratio of the domestic and the foreign inputs chosen in the original plan. It can be verified that the two parameters of the short-term technology λ and ω depend on this ratio, not the absolute values of the planned inputs. Therefore, we will express these parameters as a function of κ_1, that is, $\lambda(\kappa_1)$ and $\omega(\kappa_1)$.

The structure of the production technology is illustrated in Figure 3. This figure plots the inputs requirement (isoquant) for a given level of the composite input x_1, for the two production technologies. The isoquant of the long-term technology (darker curve) is flatter than the short-term isoquants. In the first period, the firm chooses a point along the long-term isoquant. This point can be changed in the second period but the new point must be located in the more curved isoquant.

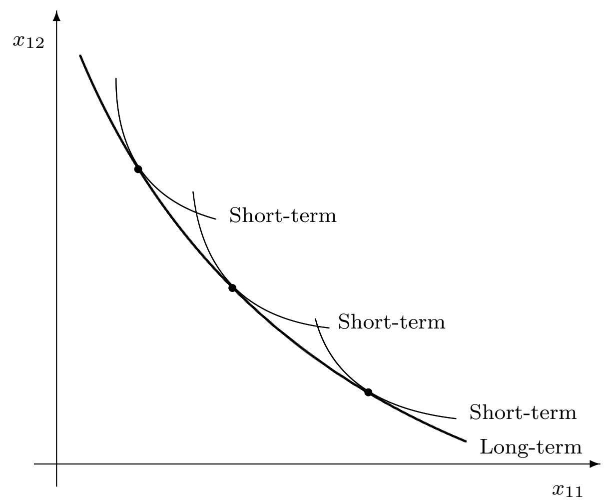


Figure 3: Isoquants for long-term and short-term production technologies.

Monetary policy: The monetary authorities control the interest rates as in the previous model. However, now it becomes important to specify when the interest rates are chosen. We will characterize the equilibrium in two policy environments. In the first environment the monetary authorities decide the interest rates in the second period, after the firms have committed to the long-term plan (Policy Discretion). In the second environment the monetary authorities decide the interest rates in the first period before the firms have chosen the long-term plan. In the second period they simply implement the policy targets decided in the first period (Policy Commitment).

II.1 Equilibrium with policy discretion

Consider the environment where the monetary authorities choose the interest rates in the second period (policy discretion). Because there are two periods, we have to distinguish the problem solved in the first period from the one solved in the second. We start with the characterization of the second period equilibrium.

Second period equilibrium for given κ_1 and κ_2: At the beginning of the period firms are already committed to the input ratios $\kappa_1 = \hat{x}_{12}/\hat{x}_{11}$ and $\kappa_2 = \hat{x}_{22}/\hat{x}_{21}$. Therefore, the parameters of the short-term production function are given. Given the interest rates and the real exchange rate, firms in country 1 solve the problem:

$$\max_{x_{11},x_{12}} \left\{ A_1\lambda(\kappa_1)^\nu \Big(x_{11}^\eta + \omega(\kappa_1)\cdot x_{12}^\eta \Big)^{\frac{\nu}{\eta}} - (x_{11} + \bar{e}\cdot x_{12})(1+R_1) \right\} \tag{15}$$

Taking the first order conditions and rearranging, the solution is:

$$x_{11} = \left(\frac{\nu A_1 \lambda(\kappa_1)^\nu}{1+R_1}\right)^{\frac{1}{1-\nu}} \left[1+\omega(\kappa_1)\left(\frac{\omega(\kappa_1)}{\bar{e}}\right)^{\frac{\eta}{1-\eta}}\right]^{\frac{\nu-\eta}{\eta(1-\nu)}} \tag{16}$$

$$x_{12} = \left(\frac{\omega(\kappa_1)}{\bar{e}}\right)^{\frac{1}{1-\eta}} x_{11} \tag{17}$$

Equations (16) and (17) are the demands for the domestic and foreign inputs. These demand functions take the same form as the demand functions derived in the one-period model. The only difference is that now the parameters of the production function depend on the previous choice of κ_1. Similar demand functions are derived for country 2.

Given the current states κ_1 and κ_2, and the interest rates chosen by the two monetary authorities, we can derive the equilibrium conditions in the goods markets and the foreign exchange market as we did in the static model. The general equilibrium is characterized by the following three equations:

$$C_1 = \left(\frac{\nu A_1\lambda(\kappa_1)^\nu}{1+R_1}\right)^{\frac{1}{1-\nu}} \left(\frac{1+R_1-\nu}{\nu}\right) \left[1+\omega(\kappa_1)\left(\frac{\omega(\kappa_1)}{\bar{e}}\right)^{\frac{\eta}{1-\eta}}\right]^{\frac{\nu(1-\eta)}{\eta(1-\nu)}} \tag{18}$$

$$C_2 = \left(\frac{\nu A_2\lambda(\kappa_2)^\nu}{1+R_2}\right)^{\frac{1}{1-\nu}} \left(\frac{1+R_2-\nu}{\nu}\right) \left[1+\omega(\kappa_2)\left(\omega(\kappa_2)\bar{e}\right)^{\frac{\eta}{1-\eta}}\right]^{\frac{\nu(1-\eta)}{\eta(1-\nu)}} \tag{19}$$

$$\left[\frac{A_1\lambda(\kappa_1)^\nu(1+R_2)}{A_2\lambda(\kappa_2)^\nu(1+R_1)}\right]^{\frac{1}{1-\nu}} = \bar{e}^{\frac{1+\eta}{1-\eta}} \left[\frac{1+\omega(\kappa_2)(\omega(\kappa_2)\bar{e})^{\frac{\eta}{1-\eta}}}{1+\omega(\kappa_1)\left(\frac{\omega(\kappa_1)}{\bar{e}}\right)^{\frac{\eta}{1-\eta}}}\right]^{\frac{\nu-\eta}{\eta(1-\nu)}} \tag{20}$$

These equations are similar to equations (18)-(20) in the analysis of the one-period model. Some of the parameters, however, are now functions of the input ratios κ_1 and κ_2. These were chosen in the previous period and they are taken as given at this stage.

Given the input ratios κ_1 and κ_2, the policy equilibrium is derived after deriving the reaction functions for the two countries. The important point, here, is that the equilibrium depend on the input ratios κ_1 and κ_2 and on the level of technology A_1 and A_2. Therefore, we can express the equilibrium interest rates as a function of these variables, that is, $(R_1, R_2) = \Psi(A_1, A_2, \kappa_1, \kappa_2)$. We will refer to this function as the "equilibrium policy rule". Similarly, we can express the equilibrium real exchange rate as a function of the same variables, that is, $\bar{e}(A_1, A_2, \kappa_1, \kappa_2)$. With this in mind, we can now study the equilibrium in the first period when κ_1 and κ_2 are determined.

First-period equilibrium: In the first period firms choose the input ratio that maximizes next period profits. These depend on the interest rates and real exchange rate determined by the functions $\Psi(\kappa_1, \kappa_2, A_1, A_2)$ and $\bar{e}(\kappa_1, \kappa_2, A_1, A_2)$ defined above.

Let $V_i(A_i, R_i, \bar{e}, k)$ be the surplus of a firm in country i, where k denotes the input ratio chosen by this firm. A brief inspection of the objective (15) shows that this surplus depends on the level of technology, the interest rate, the real exchange rate and the input ratio. The problem solved by the firm in the first period can then be written as:

$$h_i(\Psi; A_1, A_2, \kappa_1, \kappa_2) = \arg\max_k V_i\Big(A_i, \Psi_i(A_1, A_2, \kappa_1, \kappa_2), \bar{e}(A_1, A_2, \kappa_1, \kappa_2), k\Big) \tag{21}$$

The function $h_i(\Psi; A_1, A_2, \kappa_1, \kappa_2)$ gives the input ratio chosen by a firm in country i when the levels of technology are A_1 and A_2 and all other firms choose κ_1 and κ_2. This function also depends on the equilibrium policy rule Ψ. Because firms in each country are homogeneous, they will all choose the same input ratio. This implies that in equilibrium $h_i(\Psi; A_1, A_2, \kappa_1, \kappa_2)$ must be equal to κ_i. We then have the following definition:

Definition 1 (Discretionary equilibrium) *A discretionary policy equilibrium is defined by a policy rule $\Psi(A_1, A_2, \kappa_1, \kappa_2)$ and a couple (κ_1^*, κ_2^*) such that:*

(i) The policy rule Ψ solves the two-country game for given $(A_1, A_2, \kappa_1, \kappa_2)$;

(ii) The couple (κ_1^*, κ_2^*) satisfies:

$$\begin{aligned} \kappa_1^* &= h_1(\Psi; A_1, A_2, \kappa_1^*, \kappa_2^*) \\ \kappa_2^* &= h_2(\Psi; A_1, A_2, \kappa_1^*, \kappa_2^*) \end{aligned}$$

II.2 Equilibrium with commitment

With policy commitment, the interest rates are chosen in the first period. When the monetary authorities decide their policies, they understand that firms are not committed yet to the production plan. Because there is no uncertainty between the first and the second period, firms will always choose the input ratio based on the long-term technology. In this case we can ignore the short-term technology and the equilibrium is characterized as in the one-period model but with the long-term technology.

II.3 Lack of commitment and inflation bias

The important point of this section is that without the ability to commit, policy competition will induce higher interest rates and inflation. A numerical example illustrates this point. We assume that $A_1 = A_2 = 1$, $\nu = 0.9$ and we consider alternative values for the long-term elasticity $1/(1-\epsilon)$ and the short-term elasticity $1/(1-\eta)$. After choosing ϵ, the parameter ϕ is chosen such that in the equilibrium with common currencies imports are 25 percent the value of domestic net production. As shown in Table 2 the interest rates and the consumption losses increase when countries are not able to commit to future policies (discretion). Moreover the interest rate bias and the welfare losses are larger when the short-term elasticity is very different from the long-term elasticity.

Table 2: Equilibrium interest rates and consumption losses from policy competition.

	ST elasticity=1.1 LT elasticity=1.4	ST elasticity=0.9 LT elasticity=1.6	ST elasticity=0.7 LT elasticity=1.8
Policy commitment			
Interest rate	6.49	5.30	4.48
Consumption loss	1.02	0.70	0.51
Policy discretion			
Interest rate	9.67	14.14	24.40
Consumption loss	2.12	4.17	10.57

The intuition for these results are illustrated with the help of Figure 4. Consider first the equilibrium with commitment. Assume that this equilibrium is at point B. This point is associated with interest rates R_1^B and R_2^B. In evaluating the welfare consequences of a policy deviation, the monetary authorities know that firms face the flatter isoquant because they are not committed yet to the production plan. Because firms are flexible at this stage, an increase in the interest rate does not have a large impact on the real exchange rate (i.e. the *terms of trade* effect is small). As a result, the equilibrium interest rates must be relatively low.

Now consider the case of policy discretion and assume that we start from the same point B, which is the equilibrium with policy commitment. Do the monetary authorities have an incentive to increase the interest rate? The answer is yes. This is because firms are now committed to the production plan and face the more curved isoquant (they are less flexible). Consequently, a "unilateral" increase in the interest rate will have a large impact on the real exchange rate and will increase the welfare of the deviating country. Only after the interest rates have reached certain levels, do policy makers no longer have an incentive to deviate. At this point the terms of trade effect is counterbalanced by the financing cost effect. The equilibrium with policy discretion will be at point C which is characterized by higher interest rates, lower production and lower welfare.

The above two equilibria are compared to the equilibrium that would prevail if the monetary authorities coordinate their policies. In this case the interest rates would be zero independently of the moment in which these interest rates are chosen. In Figure 4 the equilibrium with policy coordination is represented by the point A.

We summarize the results of the two-period model as follows:

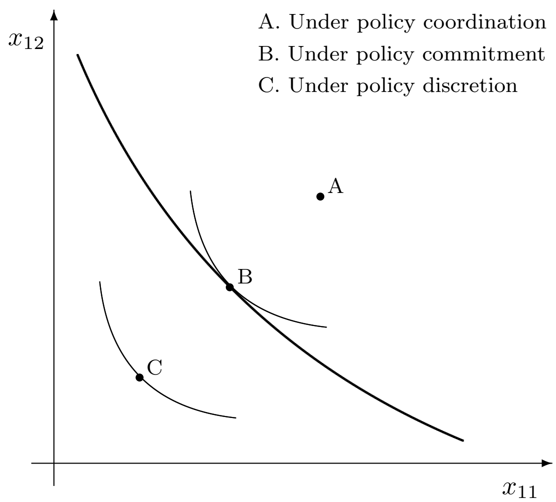


Figure 4: Equilibrium under policy commitment and policy discretion.

Result 2 (Competition, commitment and inflation bias) *Policy competition induces higher interest (and inflation) rates than policy cooperation. The bias is exacerbated by the lack of policy commitment.*

III The general model

In this section we extend the model to an infinite horizon setting and introduce aggregate shocks. In extending the model, we also specify the whole monetary/financial sector. This allows us to make precise the relationship between the nominal interest rate and the inflation rate. We retain the assumption that there are no international financial transactions (autarky). The role of capital mobility will be studied in the supplemental appendix available at the journal web site.

The general result is that the equilibrium of the infinite horizon model is simply the repetition of the two-period model studied in the previous section. The reader not interested in the specification of the whole monetary sector and in the formal establishment of this result can go directly to the quantitative analysis of the next section.

Households: Households are infinitely lived and they maximize the lifetime utility $E_0 \sum_{t=0}^{\infty} \beta^t U(c_t)$ where β is the discount factor and c_t is consumption. Households hold deposits d in domestic banks. Deposits are decided at the end of the period and households have to wait until the end of the next period before being able to change them.

In addition to bank deposits, households also own liquid assets for transaction purposes as they face a cash-in-advance constraint. Given n_i the liquid funds retained at the end of the previous period, the cash-in-advance constraint in country i is $P_i c_i \leq n_i$. The beginning-of-period financial assets are equal to the retained liquidity plus the nominal value of domestic deposits, that is, $n_i + d_i$.

Households solve a dynamic problem in their portfolio choice. Appendix B derives the optimality condition for the choice of next period deposits. This is given by:

$$E\left(\frac{U_c(c_i')}{P_i'}\right) = \beta E\left(\frac{(1+R_i')U_c(c_i'')}{P_i''}\right) \tag{22}$$

where U_c is the marginal utility of consumption and the prime denotes the next period variable (double prime denotes the variable two periods from now). This equation shows the connection between the nominal interest rate and the inflation rate. In particular, if we abstract from uncertainty and consider a steady state, the condition can be written as $P_i'/P_i = \beta(1+R_i)$. Therefore, the higher the price change between today and tomorrow and the higher is the nominal interest rate in the current period.

Production technology and the financial sector: Firms are also infinitely lived and they operate the same production technology described in the two-period model. At the end of each period they choose the optimal input ratio κ_i based on the long-term technology (11), and at the beginning of next period they choose the intermediate inputs based on the short-term technology (12). The level of technology is allowed to change stochastically over time. More specifically, we assume that $A_{i,t} = \bar{A}e^{z_{i,t}}$ where $z_{i,t}$ is a country-specific shock that follows a first order Markov process. For simplicity we assume that the shock becomes known at the end of the previous period.

Firms still need to finance the purchase of the intermediate inputs with loans denominated in domestic currency. The loan contracted by a firm in country 1 is $P_1(x_{11} + \bar{e}x_{12})$ and the loan contracted by a firm in country 2 is $P_2(x_{22} + x_{21}/\bar{e})$. Banks make loans only in the currency in which they receive deposits.

Monetary policy: The monetary authority of each country chooses the policy instrument (interest rate) optimally in the sense of maximizing the welfare of the domestic households, taking as given the policy strategy of the other country. We first consider the case of time-consistent policies meaning that the monetary authorities cannot commit to future policies. In the class of time-consistent policies we restrict the analysis to Markov strategies, that is, policies that depend only on the current (physical) states of the economy. The equilibrium of this environment will be contrasted with two alternatives: an environment where the monetary authorities choose the whole sequence of state contingent interest rates today (Ramsey-type policy with commitment) and one where the monetary authorities coordinate their policies (common currency).

The monetary authorities choose the interest rates by controlling the domestic monetary aggregates. The monetary aggregate, in turn, is controlled by making transfers to households in the form of bank deposits. The pre-transfer monetary aggregate in country i is denoted by M_i and the monetary transfer by $T_i = g_i M_i$, where g_i is the growth rate of money. Because transfers are in the form of bank deposits, higher transfers increase the liquidity available to domestic intermediaries to make loans. By limiting the ability of households to readjust their portfolio of deposits, the increase in liquidity induces a fall in the nominal interest rate. This is the liquidity effect of limited participation models such as Christiano & Eichenbaum (1995), Fuerst (1992) and Lucas (1990).

Market clearing conditions: The equilibrium conditions in the goods markets do not change and they are still given by equations (5) and (6). Because we keep the assumption that there are no international financial transactions, the equilibrium condition in the exchange rate market is still (7). The equilibrium conditions in the loan markets are:

$$P_1(X_{11} + \bar{e} \cdot X_{12}) = D_1 + T_1 \quad (23)$$

$$P_2(X_{22} + X_{21}/\bar{e}) = D_2 + T_2 \quad (24)$$

The left-hand-side is the demand for loans from domestic firms and the right-hand-side is the supply of loans from domestic banks. The supply of loans is given by the deposits of domestic residents, D_i, and the monetary injection, T_i.

These equilibrium conditions can be used to derive the relation between the interest rate and the growth rate of money. This relation is characterized in the following lemma.

Lemma 1 *The nominal interest rate in country i is determined by the domestic growth rate of money according to* $R_i = \frac{1+g_i}{D_i/M_i+g_i} - 1$.

Proof: *Appendix C.*

This lemma tells us that, given the stocks of deposits, there is a unique relationship between the domestic growth rate of money and the domestic interest rate. Moreover, the domestic interest rate is not affected by the interest (and money growth) rate in the other country. This implies that the specification of the monetary policy instrument in terms of money growth rate or interest rate is equivalent.

For economy of space, the definitions of equilibria and the derivation of the main properties of the model are provided in the supplemental appendix available at the journal web site. Here we simple state the main results in the form of three propositions.

Proposition 1 (Discretionary equilibrium) *The Markov perfect equilibrium of the repeated policy game is the equilibrium of the two-period model defined in Section II.1.*

Proposition 2 (Ramsey equilibrium) *The Ramsey policy equilibrium is the equilibrium under policy commitment of the two-period model defined in Section II.2.*

Proposition 3 (Common currency equilibrium) *With common currencies the optimal policy is the Friedman rule of a zero interest rate independently of whether the monetary authority can commit to future policies.*

Therefore, the infinite horizon model can be seen as a simple repetition of the two periods model. The infinite horizon structure, however, allows us to define the inflation and interest rates as part of the equilibrium of the monetary sector.

IV Quantitative analysis

We parameterize the model using data from the 11 European countries that became members of the European Monetary Union in 1999. This is because the EMU is the most important example of monetary unification in recent years. We think of the two-country game as capturing the strategic interaction among the original EMU members.[4]

The period in the model is a quarter and the discount factor is $\beta = 0.995$. We assume logarithmic utility, that is, $U(c) = \log(c)$.

The production technology is characterized by the parameters ν, ϕ, η, ϵ, and by the level of technology $A_i = e^{z_i}$, where z_i is the shock in country i. To calibrate ν we observe that the fraction of liquid funds used by households for transaction purposes is approximately equal to $1 - \nu$.[5] If we take the monetary aggregate M1 as the measure of liquid funds used for transaction by households and M3 as the measure of their total financial assets, then the average ratio of these two aggregates determines $1 - \nu$. Therefore, we set ν =1-M1/M3=0.9 which is in the order of values for the EMU countries.

The parameters η and ϵ determine the degree of substitutability between domestic and foreign inputs in the short-run and in the long-run. Reinert & Roland-Holst (1992) estimates the Armington elasticities at the industry level for the U.S. manufacturing sector and they find an average elasticity is 0.9. These are short-term elasticities. Gallaway et al. (2000) estimate both the short-term and long-term elasticities and they find that on average the latter are about twice as large. Although these estimates are not for the European countries, there is not reason to believe that they are dramatically different.[6] Based on these numbers we set $1/(1 - \eta) = 0.9$ and $1/(1 - \epsilon) = 1.6$. These elasticities are not very different from the values used in international business cycles studies. For example, Backus, Kehoe, & Kydland (1994) use an elasticity of 1.5 and Stockman & Tesar (1995) use an elasticity of 1. We will also conduct a sensitivity analysis.

After fixing η and ϵ, the value assigned to ϕ is such that in the steady state with discretionary policies the value of imports plus export (the openness index) is 50 percent

[4]The group of countries that became part of the EMU in 1999 includes Austria, Belgium, Germany, Finland, France, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain.

[5]It will be exactly $1 - \nu$ if the interest rate is zero.

[6]If there are differences, it is likely that European elasticities are smaller than in the U.S. See chapter 3 in Deardoff & Stern (1990) and chapter 5 in Whalley (1985). This would strengthen our results.

the value of net output (GDP). This is the average value of imports plus export for the EMU countries weighted by their relative size at the end of the 1970s (see OECD historical statistics 1970-2000). We consider the end of 1970s as the starting point of the current unification. In fact, 1979 was the starting date for the European Monetary System. The value of ϕ that generates the desired openness target is 0.117.

We assume that in both countries the technology shock follows the autoregressive process $z' = \rho_z z + \varepsilon$ with $\rho_z = 0.95$. The innovations ε_1 and ε_2 are jointly normal with mean zero. Specifically we assume that $\varepsilon_1 = \rho_\varepsilon \varepsilon_2 + \upsilon$ where $\varepsilon_1 \sim N(0, \sigma_\varepsilon^2)$ and $\upsilon \sim N(0, \sigma_\upsilon^2)$. We will consider several values of ρ_ε. Once we have ρ_ε, the other two parameters, σ_ε and σ_υ, are calibrated so that the volatility of aggregate output in the model is equal to the average GDP volatility in the EMU countries.

IV.1 Loss of long-term monetary independence

We start by analyzing the quantitative properties of the model when there is no uncertainty, that is, $z_1 = z_2 = 0$. Table 3 reports the equilibrium inflation rates, interest rates and welfare losses from policy competition with and without commitment. The equilibrium is computed for different elasticities of substitution between domestic and foreign inputs in the short-term and in the long-term. The welfare losses are the percentage decrease (or increase if negative) in consumption relative to the common currency.

Table 3: Equilibrium inflation, interest rates and consumption losses relative to a common currency. Values are in annual percentage.

	(*Baseline model*) ST elasticity=0.9 LT elasticity=1.6	ST elasticity=0.7 LT elasticity=1.8	ST elasticity=1.1 LT elasticity=1.4
Policy commitment			
Inflation	3.22	2.41	4.37
Interest rate	5.31	4.48	6.49
Consumption loss	0.70	0.51	1.02
Policy discretion			
Inflation	11.90	21.93	7.49
Interest rate	14.10	24.40	9.67
Consumption loss	4.17	10.57	2.12

With common currencies the equilibrium nominal interest rate is zero and the inflation rate is equal to $\beta - 1 = -0.0198$. As stated in proposition 3, the Friedman rule of a zero nominal interest rate is the optimal policy. However, without coordination, each country has an incentive to deviate which explains the higher inflation and interest rates. Because both countries will deviate from the Friedman rule in absence of coordination, neither of them will benefit from the higher interest rates. The inflation bias and the welfare losses are larger when the monetary authorities cannot commit to future policies.

In this case the welfare gains from policy coordination are quite large, about 4 percent of consumption. When the monetary authorities commit to future policies, the welfare gain from policy coordination fall to 0.7 percent.

The second and third columns of Table 3 repeat the calculation for different elasticities. The inflation bias increases with the degree of complementarity between domestic and foreign imports. The inflation bias almost vanishes when domestic and foreign imports are good substitutes and the monetary authorities can commit to future policies.

Although the EMU countries now have coordinated policies, they are still trading with countries that are not part of the Union. Therefore, they are still facing some strategic interaction. However, the area as a whole is now less dependent on trade. Accordingly, a better evaluation of the impact of the European Monetary Union would compare the equilibrium under policy competition after reducing the dependence on trade. More specifically, the openness index (imports plus export as a percentage of GDP) of the EMU area is about 50 percent if we include infra-EMU trade, but only half of this is with countries outside the Union. Table 4 reports the welfare gains after reducing the trade dependence by half. This is obtained by changing the value of the parameter ϕ such that in the steady state the volume of imports (and exports) is 12.5 percent of output in the competitive equilibrium with discretionary policies. As can be seen from the table, the welfare consequences are significant even if countries do not suffer from internal commitment problems in the conduct of monetary policy.

Table 4: Steady state equilibrium inflation, interest rates and consumption gains before and after the monetary integration of Europe. Values are in annual percentage.

	With policy commitment	With policy discretion
Pre-integration		
Inflation	3.21	11.87
Interest rate	5.30	14.14
Post-integration		
Inflation	0.56	5.05
Interest rate	2.59	7.17
Consumption gain	0.52	2.51

The previous calculations assume that countries are symmetric in technology and size. However, many cases of monetary integration involves countries that are in different stages of economic development and are of different size. Therefore, we now allow for different population sizes. The case with differences in per-capita output are similar. Because larger countries are likely to be less dependent on trade, we also assume that they have lower values of ϕ (but they have the same ϵ and η).

Table 5 reports the equilibrium values when the population of country 2 is twice and five times bigger than country 1 (μ denotes the population of country 2 relative to the population of country 1). The first point to observe is that the interest and inflation rates are higher in the country that is more dependent on trade, that is, the smaller country. Moreover, as could be anticipated from the previous section, the inflation and interest rates are higher when the countries are unable to commit to future policies. The second point to observe is that when the first country is sufficiently small and it is able to commit to future policies, the adoption of the common currency might bring negative welfare consequences. This is because for the larger country the negative financing cost effect of a higher interest rate is relatively more important than the positive terms of trade effect. Therefore, it will have a lower incentive to increase the interest rate. Because a higher interest rate of the smaller country is accompanied by a smaller interest rate from the larger country, the former could gain from policy competition. This is more likely to be the case when the small country is able to commit to future policies.

Table 5: Steady state equilibrium inflation, interest rates and consumption losses relative a common currency when countries are heterogeneous. Values are in annual percentage.

	$\mu = 2$		$\mu = 5$	
	Country 1	Country 2	Country 1	Country 2
Policy commitment				
Inflation	3.44	1.47	3.64	0.06
Interest rate	5.53	3.53	5.74	2.08
Consumption loss	0.24	0.67	-0.34	0.33
Policy discretion				
Inflation	14.23	6.85	16.84	3.06
Interest rate	16.55	9.02	19.21	5.15
Consumption loss	3.30	3.28	2.55	2.11

The case of $\mu = 5$ can be interpreted as capturing the position of the UK vis-a-vis the EMU. The total population of the EMU countries is in fact about 5 times the population of the UK. At the same time, the per-capita income of the UK is not very different from the EMU average, as assumed in the numerical experiment. Therefore, if we believe that the UK does not have commitment problems, the above exercise suggests that the UK would not gain from adopting the Euro. Notice that the model predicts that the UK should have higher interest and inflation rates than the EMU countries and an appreciated real exchange rate. This seems to be the case in the second half of 1990s. For other countries that have commitment problems, instead, the adoption of the Euro could be the optimal strategy.

IV.2 Loss of cyclical monetary policy independence

Figures 5 reports the impulse responses of several variables after a positive technology shock in country 1 when shocks are not correlated. Therefore, the level of technology in country 2 remains constant. Three different policy environments are considered: (i) common currency; (ii) strategic interaction with commitment; (iii) strategic interaction without commitment. Each column of Figure 5 refers to one of the three environments.

With a common currency the Friedman rule is optimal and the interest rates remains constant. When countries interact strategically, instead, they respond to the shock by changing the interest rates. Country 1 responds by lowering the interest rate while the reverse takes place in country 2. The interest rate responses are larger when the countries conduct discretionary monetary policy. However, in both cases of discretion and commitment, the response of the interest rates are quantitatively negligible.

In terms of money supply, both countries increase the growth rate of money (except in the first period and for the second country). This monetary expansion is necessary to allow output to expand. Plots (c.1)-(c.3), in fact, shows that the outputs of both countries increase. Although technology shocks are not correlated between countries, the shock in country 1 is transmitted to country 2 through the real exchange rate. Due to the higher demand of foreign goods, the real exchange rate in country 1 depreciates ($\bar{e}$ increases) as can be seen from figures (d.2) and (d.3). The depreciation in country 1 corresponds to an appreciation in country 2. This makes foreign inputs cheaper for the second country and induces an economic expansion.

In order to compute the welfare costs of losing cyclical monetary policy independence, we compare the expected welfare reached under monetary independence with the expected welfare reached when the nominal interest rate is kept constant at its long-term value. The constancy of the interest rate captures the cyclical properties of the optimal monetary policy under a common currency and characterizes the situation faced by the two countries if they lose the ability to react optimally to shocks. The welfare consequences are extremely small, almost insignificant. In all calculations they are less than 0.01 percent of consumption, independently of the correlation structure of the shocks.

This result is obvious once we observe that the responses of output are almost identical under the three policy regimes (see plots (c.1)-(c.3)). This derives from the fact that the responses of the interest rates are small (see plots (a.2)-(a.3)). This result, when evaluated in conjunction with the results of the previous section, shows that the possible gains or losses from a common currency derive from the changes in the long-term inflation and interest rates. The loss of the ability to react optimally to internal or external shocks is of secondary concern.

V Conclusion

In this paper we have studied the welfare consequences of adopting a common currency as a way to achieve monetary policy coordination in a two-country open economy model. In this economy the inflation rate is not neutral even if it is perfectly predicted because it leads to higher nominal interest rates which in turn distort the allocation of resources. Within this framework we show that policy competition leads to higher inflation and interest rates than policy coordination. Moreover, this inflation and interest bias is exacerbated by the inability of the monetary authorities to commit to future policies.

If the competing countries are sufficiently homogeneous, they all benefit from coordinating their policies. However, if countries are not homogeneous (for example they have different population sizes) and they do not have problems of policy commitment, then it is not necessarily the case that they all benefit from adopting the common currency. On the other hand, for countries that find difficult to commit to future policies, monetary integration is more likely to bring benefits to all countries even if they are heterogeneous. In all cases, however, the net gains from policy coordination are positive.

Our model (and conclusion) differs from the "new open economy macroeconomic models" in several dimensions. Firstly, in our framework producers do not operate in monopolistic competitive markets and production is not necessarily inefficient. Secondly, money is used for transaction by households and firms, and monetary policy interventions have liquidity effects. Thirdly, prices are perfectly flexible. Therefore, the channel through which monetary expansions affect the real sector of the economy is not by increasing the nominal aggregate demand but through the reduction in the financing cost of firms. These modeling differences lead to the result that international monetary policy competition lead to an inflation bias with significant welfare consequences.

Appendix

A Derivation of equations (8)-(10)

The final goods productions and the equilibrium in exchange rate market are:

$$C_1 = A_1[X_{11}^{\epsilon} + \phi X_{12}^{\epsilon}]^{\frac{\nu}{\epsilon}} - X_{11} - \bar{e}X_{12} \tag{25}$$

$$C_2 = A_2[X_{22}^{\epsilon} + \phi X_{21}^{\epsilon}]^{\frac{\nu}{\epsilon}} - X_{22} - X_{21}/\bar{e} \tag{26}$$

$$\bar{e}X_{12} = X_{21} \tag{27}$$

The solutions of the firms' problem in country 1 and 2 (see problem (2)) are:

$$X_{11} = \left(\frac{\nu A_1}{1+R_1}\right)^{\frac{1}{1-\nu}} \left[1 + \phi\left(\frac{\phi}{\bar{e}}\right)^{\frac{\epsilon}{1-\epsilon}}\right]^{\frac{\nu-\epsilon}{\epsilon(1-\nu)}} \tag{28}$$

$$X_{12} = \left(\frac{\phi}{\bar{e}}\right)^{\frac{1}{1-\epsilon}} X_{11} \tag{29}$$

$$X_{22} = \left(\frac{\nu A_2}{1+R_2}\right)^{\frac{1}{1-\nu}} \left[1 + \phi\left(\phi\bar{e}\right)^{\frac{\epsilon}{1-\epsilon}}\right]^{\frac{\nu-\epsilon}{\epsilon(1-\nu)}} \tag{30}$$

$$X_{21} = (\phi\bar{e})^{\frac{1}{1-\epsilon}} X_{22} \tag{31}$$

Using these conditions to eliminated X_{11}, X_{12}, X_{21} and X_{22} in equations (25)-(27) we get equations (8)-(10).

B Derivation of condition (22)

Assume that the interest rates are determined by the policy rule $\Psi(\mathbf{s})$ where $\mathbf{s}$ are the aggregate states of the economy. In order to use a recursive formulation, we normalize all nominal variables by the pre-transfer stock of money in which the variables are denominated (either M_1 or M_2). After this normalization the aggregate states of the economy are $\mathbf{s} = (A_1, A_2, D_1, D_2)$. The individual households' states are n_i and d_i, where n_i are the liquid assets used for transaction and d_i are the bank deposits. The problem solved by a household in country i is:

$$\Omega_i(\mathbf{s}, n_i, d_i) = \max_{d_i'} \Big\{ u(c_i) + \beta\, E\, \Omega_i(\mathbf{s}', n_i', d_i') \Big\} \tag{32}$$

subject to

$$c_i = \frac{n_i}{P_i} \tag{33}$$

$$n_i' = \frac{(d_i + g_i)(1+R_i) + P_i\pi_i}{(1+g_i)} - d_i' \tag{34}$$

$$R_i = \Psi_i(\mathbf{s}) \tag{35}$$

$$\mathbf{s}' = H(\mathbf{s}) \tag{36}$$

The first order condition gives (22).

C Proof of lemma 1

Because $M_1 = D_1 + N_1$, using the cash-in-advance and equations (5) and (23), we get:

$$P_1 Y_1 + P_1 (\bar{e} \cdot X_{12} - X_{21}) = M_1 + T_1 \tag{37}$$

which expresses the equality between the volume of transactions executed with the use of domestically denominated liquid funds, and the total quantity of these funds. For country 2, the analog of condition (37) is:

$$P_2 Y_2 - \frac{P_2}{\bar{e}} (\bar{e} \cdot X_{12} - X_{21}) = M_2 + T_2 \tag{38}$$

Using the equilibrium condition in the exchange market (7), equations (37) and (38) become:

$$P_1 Y_1 = M_1 + T_1 \tag{39}$$

$$P_2 Y_2 = M_2 + T_2 \tag{40}$$

After eliminating P_1 in equation (39) using the equilibrium condition in the loans market (equation (23)) we get:

$$\frac{Y_1}{X_{11} + \bar{e} X_{12}} = \frac{M_1 + T_1}{D_1 + T_1}$$

Using the production function (12) and the solutions for the firm problem (equations (16) and (17)), it can be verified that the left-hand-side of the above equation is equal to $(1 + R_1)M_1$. After dividing by M_1, we get the expression for the interest rate. *Q.E.D.*

References

Atkeson, A. & Kehoe, P. J. (1999). Models of energy use: putty-putty versus putty-clay. *American Economic Review*, *89*(4), 1028–43.

Backus, D. K., Kehoe, P. J., & Kydland, F. E. (1994). Dynamics of the trade balance and the terms of trade: the j curve?. *American Economic Review*, *84*, 84–103.

Benigno, G. & Benigno, P. (2001). Price stability as a nash equilibrium in monetary open-economy models. CEPR Working Paper No. 2757.

Canzoneri, M. B., Cumby, R. E., & Diba, B. T. (2001). The need for international policy coordination: what's old, what's new, what's yet to come?. Unpublished manuscript,Georgetown University.

Chari, V. V. & Kehoe, P. J. (2002). Time inconsistency and free-riding in a monetary union. NBER Working Paper Series # 9370.

Christiano, L. J. & Eichenbaum, M. (1995). Liquidity effects, monetary policy, and the business cycle. *Journal of Money Credit and Banking*, *27*(4), 1113–36.

Cooper, R. W. & Kempf, H. (2001). Dollarization and the conquest of hyperinflation in divided societies. *Quarterly Review, Federal Reserve Bank of minneapolis*, *25*(3), 3–12.

Corsetti, G. & Pesenti, P. (2001a). International dimensions of optimal monetary policy. FRBNY Staff Report No. 124.

Corsetti, G. & Pesenti, P. (2001b). Welfare and macroeconomic interdependence. *Quarterly Journal of Economics*, *116*(2), 421–46.

Corsetti, G., Pesenti, P., Roubini, N., & Tille, C. (2000). Competitive devaluations: toward a welfare-based approach. *Journal of International Economics*, *51*(1), 217–41.

Deardoff, A. V. & Stern, R. M. (1990). *Computational Analysis of Global Trading Arrangements*. University of Michigan Press, Ann Arbor, Michigan.

Fuerst, T. S. (1992). Liquidity, loanable funds, and real activity. *Journal of Monetary Economics*, *29*(4), 3–24.

Gallaway, M. P., McDaniel, C. A., & Rivera, S. A. (2000). Long-run industry-level estimates of U.S. armington elasticities. Office of Economics Working Paper, U.S. International Trade Commission.

Grilli, V. & Roubini, N. (1992). Liquidity and exchange rates. *Journal of International Economics*, *32*(2), 339–52.

Lucas, R. E. (1990). Liquidity and interest rates. *Journal of Economic Theory*, *50*(2), 273–64.

Obstefeld, M. & Rogoff, K. (2000a). Do we really need a new international monetary compact?. NBER Working Paper No. 7864.

Obstefeld, M. & Rogoff, K. (2000b). New directions for stochastic open economy models. *Journal of International Economics*, *50*(1), 117–53.

Pappa, E. (2000). Do the ecb and the fed really need to cooperate? optimal monetary policy in a two-country world. Unpublished manuscript, London School of Economics.

Persson, T. & Tabellini, G. (1995). Double-edged incentives: institutions and policy coordination. In Rogoff (Ed.), *Handbook of International Economics*, Vol. III, chap. 7. North Holland, Amsterdam.

Reinert, K. A. & Roland-Holst, D. W. (1992). Armington elasticities for united states manufacturing sectors. *Journal of Policy Modeling*, *14*, 631–39.

Rogoff, K. (1985). Can international monetary cooperation be counterproductive?. *Journal of International Economics*, *181*(1), 199–217.

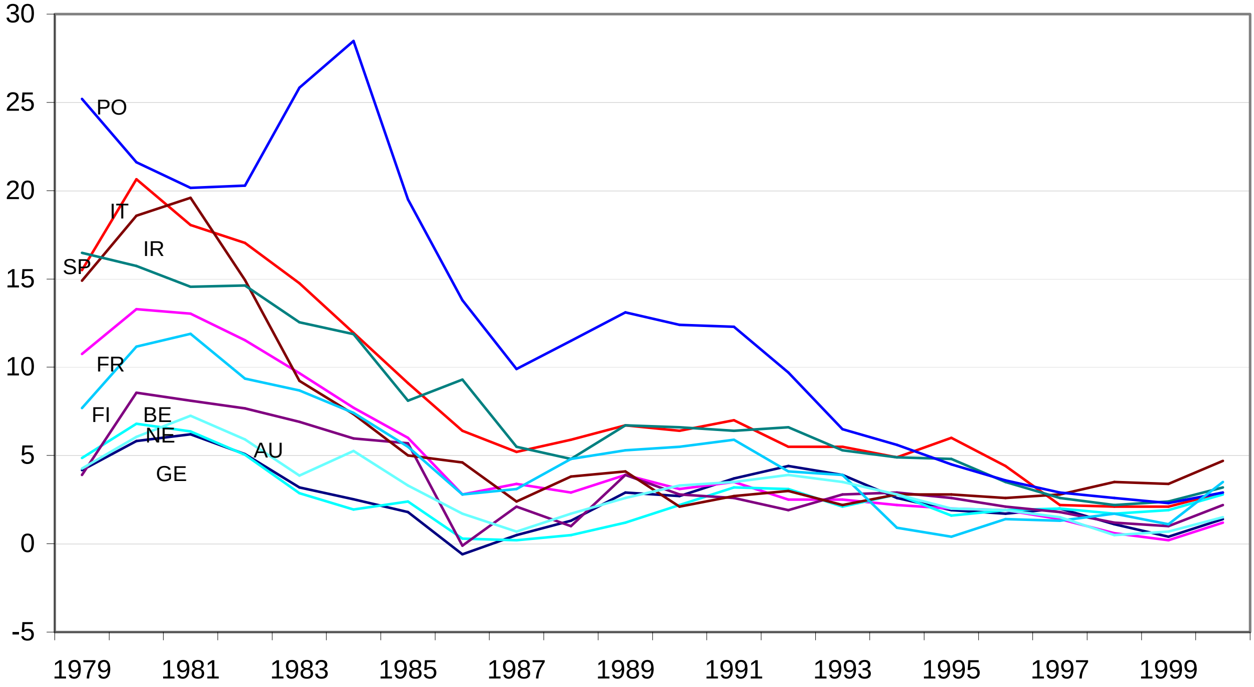
Schlagenhauf, D. E. & Wrase, J. M. (1995). Liquidity and real activity in a simple open economy model. *Journal of Monetary Economics*, *35*(3), 431–61.

Stockman, A. C. & Tesar, L. L. (1995). Tastes and technology in a two-country model of the business cycle: explaining international comovements. *American Economic Review*, *85*(1), 168–85.

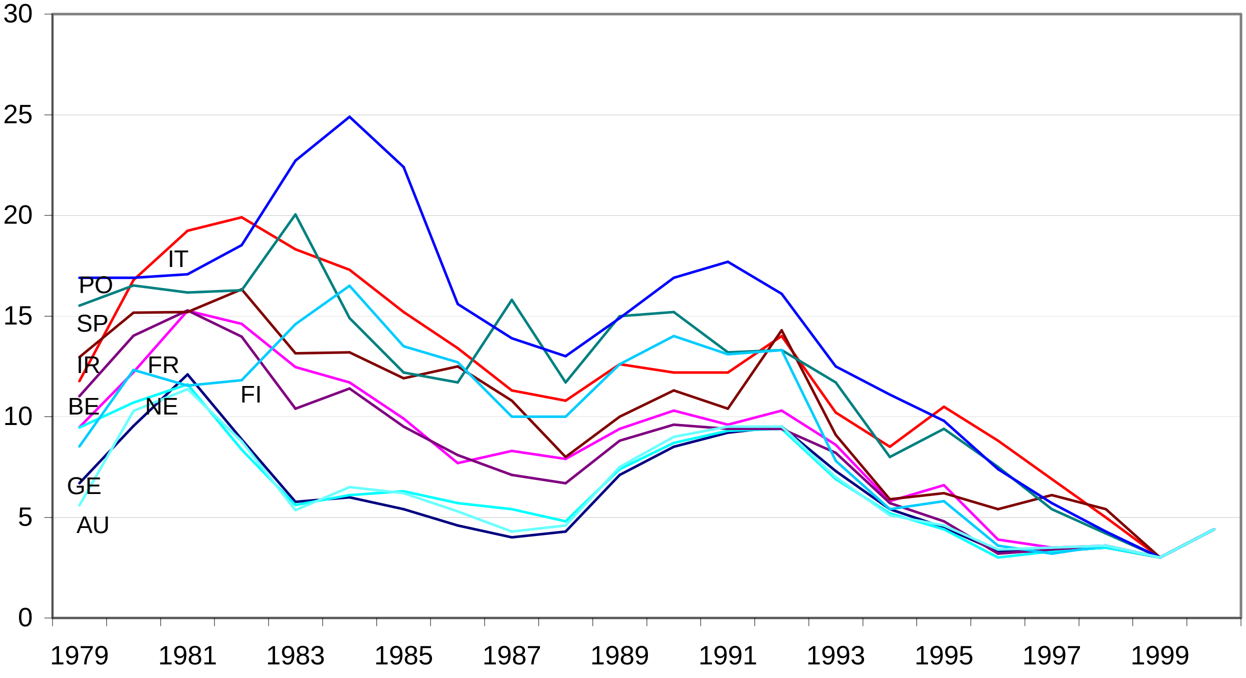
Uhlig, H. (2002). One money, but many fiscal policy in europe: what are the consequences?. Discussion paper 2002-31, Center for Economic Research, Tilburg University.

Whalley, J. (1985). *Trade Liberalization Among Trading Areas.* MIT Press, Cambridge, Massachussets.

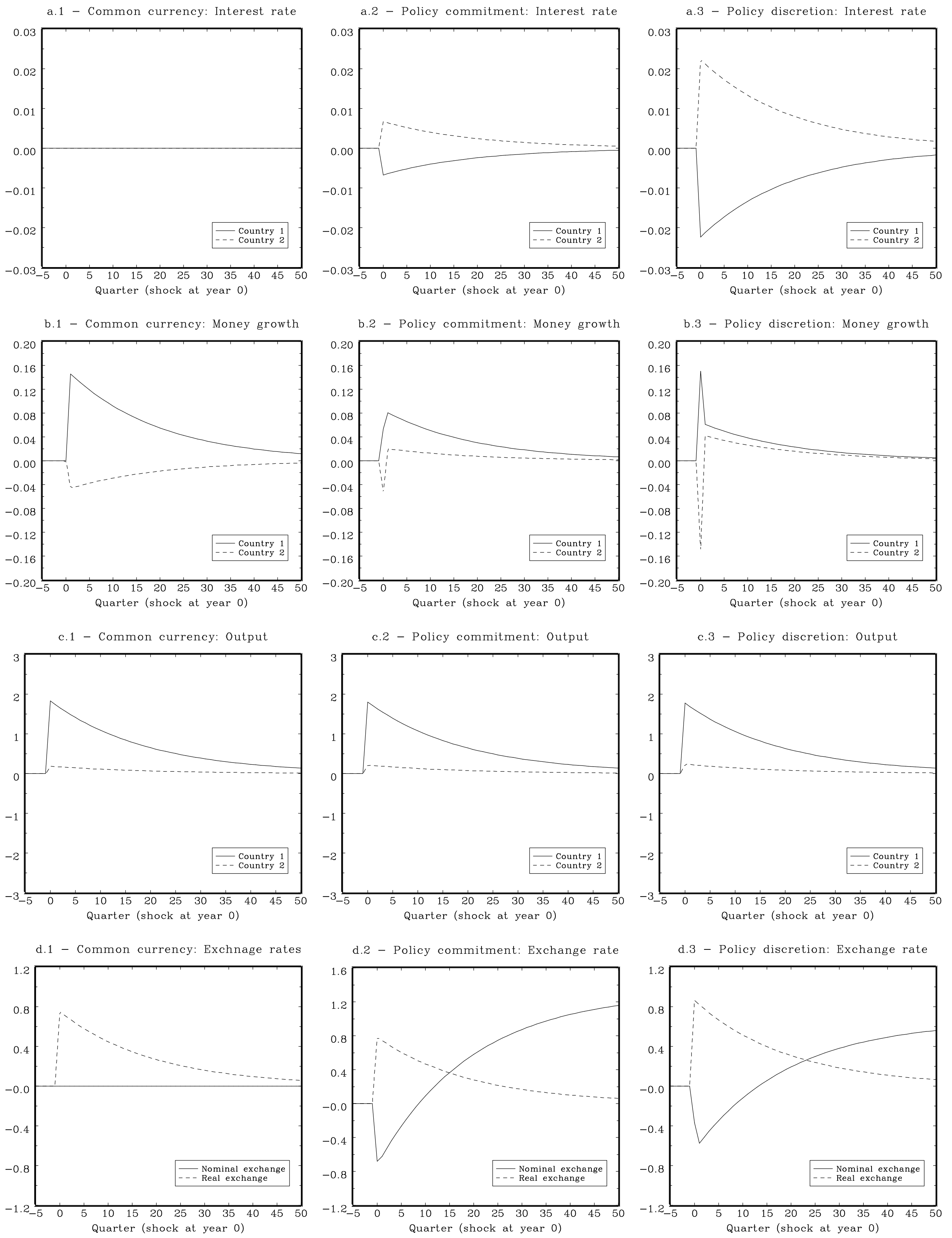
a - Inflation rates



b - Short-term interest rates



Source: OECD historical statistics 1970-2000


a.1 – Common currency: Interest rate
a.2 – Policy commitment: Interest rate
a.3 – Policy discretion: Interest rate
b.1 – Common currency: Money growth
b.2 – Policy commitment: Money growth
b.3 – Policy discretion: Money growth
c.1 – Common currency: Output
c.2 – Policy commitment: Output
c.3 – Policy discretion: Output
d.1 – Common currency: Exchnage rates
d.2 – Policy commitment: Exchange rate
d.3 – Policy discretion: Exchange rate
Country 1
Country 2
Nominal exchange
Real exchange
Quarter (shock at year 0)