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**Cite this version:**

Pappa, E. (2004). Do the ECB and the Fed really need to cooperate? Optimal monetary policy in a two-country world [online]. London: LSE Research Online.

Available at: <http://eprints.lse.ac.uk/archive/00000512>

This is an electronic version of an Article published in the Journal of monetary economics, 51 (4). pp. 753-779 © 2004 Elsevier Science B.V.

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# Do the ECB and the Fed really need to Cooperate? Optimal Monetary Policy in a Two-Country World\*

Evi Pappa<sup>†</sup>

August 2002  
(First Draft: May 2000)

## Abstract

A two-country model with monopolistic competition and price stickiness is employed to investigate the implications for macroeconomic stability and the welfare properties of three international policy arrangements: (a) cooperative, (b) non-cooperative and (c) monetary union. I characterize the conditions under which there is scope for policy cooperation and quantify the costs of non cooperation and monetary union. The non-cooperative equilibrium may be suboptimal because of *beggar-thy-neighbor* and *beggar-thyself* effects, while monetary union may be suboptimal because of the sluggishness of relative prices. Both the costs of policy competition and of a monetary union are sensitive to the values assumed for the intertemporal and international demand elasticity and the degree of openness of the economy. Independently of the calibration scenario adopted, the ECB has little to gain by coordinating with the Fed.

*JEL Classification:* E52; F41; F42

*Keyword(s):* International policy arrangements; terms of trade; openness; international demand elasticity; intertemporal demand elasticity; optimal monetary policy

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\*I would like to thank Gianluca Benigno, Fabio Canova, Ed Nelson, Morten Ravn, Tommaso Monacelli and seminar participants at several universities for useful comments. I owe special thanks to Jordi Gali for his invaluable advice.

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# 1 Introduction

The aftermath of the European Monetary Union has changed the way macroeconomic policy has been conducted within and outside Europe. The establishment of a common currency has in fact created a major rival to the dollar and yen in the international financial markets. One question of crucial importance for developments in the world economy is whether the central banks of the United States, Japan and Europe should cooperate or not in pursuing stabilization policies. The purpose of this paper is to study the welfare properties and the implications for macroeconomic stability of different international monetary policy arrangements and to investigate whether and how the first best solution can be implemented in a decentralized setting.

To address the questions of interest, I use a two-country model where each country is specialized in the production of a bundle of differentiated goods, production is monopolistically competitive, prices are staggered and there is no international price discrimination. Within this framework, I examine three types of international policy arrangements: (a) cooperative, (b) non-cooperative and (c) monetary union. Cooperation is modelled by assigning the conduct of monetary policy to a "supranational institution" that maximizes a weighted average of the utility of the consumers of both countries. Non-cooperation occurs when each central bank independently maximizes the utility of the domestic consumers taking as given foreign policy variables. Finally, monetary union can be viewed as "constrained cooperation," since the monetary authority can only use the interest rate to achieve its goals, while the exchange rate is fixed. I consider policies under commitment: the monetary authorities cannot ignore past decisions and thus the policies analyzed are not, in general, time consistent in the sense of Kydland and Prescott (1977).

The question of whether central banks should coordinate their policy actions is not new. Many authors in the past have analyzed similar issues:

Hamada (1974), Oudiz and Sachs (1984) and Rogoff (1985) are early contributors to the literature. Corsetti and Pesenti (2001a, b) Obstfeld and Rogoff (2000) and Benigno and Benigno (2002) are more recent efforts.

In this paper, I study the sources of conflict between the monetary policy objectives of two large economies and the extent to which different types of international policy arrangements may help overcome the suboptimality resulting from decentralized, non-cooperative decisions. I use a theoretical framework which encompasses the models of Corsetti and Pesenti (2001a,b), Obstfeld and Rogoff (2000) and Benigno and Benigno (2002) as specific cases. Contrary to these authors', the general preferences specification adopted enables me to characterize the conditions under which there is scope for international policy coordination, quantify the costs of the suboptimal monetary arrangements for different values of key parameters (such as openness, substitutability between home and foreign goods and labor supply elasticity) and to assess the magnitude of the gains from cooperation. Like previous work, the analysis finds that there is relatively little scope for cooperation under either sets of arrangements. However, contrary to the existing literature, it precisely pins down the logic of this result.

Optimal policies are derived using an objective criterion that approximates the utility of the representative consumer. Rotemberg and Woodford (1998) first derived this objective for a closed economy. In an open economy the central bank is concerned not only with the variability of inflation and the output gap; it also takes into account the dynamics of the terms of trade and its interaction with domestic demand. Relative prices enter the welfare criterion because they play a crucial role in the transmission of foreign shocks. It is the concern about optimal reallocation of resources between the two economies that translates in an objective for the social planner which includes the variability of the deviations of the terms of trade and the covariance between domestic consumption and relative price depreciations.

I show that the objective of independent central banks and of the so-

cial planner coincide when three conditions are satisfied: the elasticity of substitution between home and foreign goods and the intertemporal elasticity of substitution are equal to one and the degree of openness of the two economies is small. In this case, since terms of trade movements have no effect on domestic consumption and inflation and there are no incentives for policy competition and thus no gains from international policy coordination. (as in Corsetti and Pesenti (2001b) and Benigno and Benigno (2002)). For unitary international demand elasticity cross-country consumptions are equalized in equilibrium, independently of terms of trade movements. However, when this elasticity is different from one, terms of trade movements affect relative consumption movements and national policymakers have incentives to use strategically the terms of trade to improve domestic relative welfare. The value of the intertemporal elasticity of substitution is also crucial for determining the incentives for policy competition: when preferences are not logarithmic foreign variables affect domestic inflation through terms of trade movements and this foster competition among national policymakers.

Under the general specification employed, monetary policies are strategic substitutes and coordinating monetary policy is potentially beneficial. Optimal policy under cooperation always achieves the first best and completely stabilizes domestic prices in each country. The magnitude of the costs from international policy competition depend on the parametrization of the model: they increase with the coefficient of relative risk aversion and the international demand elasticity; with the labor supply elasticity and with the degree of openness of the economy.

Because sustaining a (time-consistent) cooperative agreement between the two countries is difficult, I also analyze the welfare implications of a monetary union, an arrangement which can be viewed as "cooperation with one instrument only" (the union-wide nominal interest rate). A monetary union might generate welfare costs, because the distortions associated with

the inertia of the terms of trade might dominate the gains of coordination (See, also Cooley and Quadrini (2002)). In the case of highly substitutable domestic and foreign goods, sufficiently flexible domestic prices, and little home-bias in consumption, a monetary union improves upon non-cooperative outcomes.

Should the ECB and the Fed cooperate? The answer is quite robust for a wide range of parameter values and model specifications: although policy cooperation does improve welfare, gains are quantitatively small. In order to generate significant gains from policy coordination, one has to assume high degree of trade links between the Euro area and the US and unrealistically high values for the international elasticity of substitution and for the risk aversion coefficient. However, when we ask whether the UK should join the EMU, we find that gains are significant.

The paper is organized as follows. The next section describes the model. Section 3 presents the welfare objective of the central bank in an open economy and Section 4 the calibration of the model. Section 5 studies optimal monetary policy for each of the policy regimes. Section 6 presents simulation results for a range of values of crucial parameters and Section 7 compares non-cooperation with monetary union. Section 8 concludes. The appendices contain the derivations of the relationships used.

## **2 The Model**

Since the model is somewhat standard, I only briefly outline its features. The economy consists of two countries. Each country is populated by identical, infinitely lived agents. There is no migration. Each agent produces a single differentiated good and consumes the goods produced in both economies.

## 2.1 Consumers

The consumption good is a composite of domestic and foreign goods:

$$C = [(1 - \alpha)^{\frac{1}{\eta}} C_H^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}} C_F^{\frac{\eta-1}{\eta}}]^{\frac{\eta}{\eta-1}} \quad (1)$$

where  $C_H(C_F)$  is a CES composite of the domestic (foreign) consumption bundle and the elasticity of substitution between domestic goods is  $\theta > 1$ ;  $\eta$  is the elasticity of substitution between foreign and domestic goods and  $(1 - \alpha)$  measures the degree of home bias in consumption. I assume that  $\eta \leq \theta$  i.e., there is less substitutability across countries than within countries. If  $\alpha = \frac{1}{2}$ , there is no home bias in consumption; that is, for any given relative price, domestic and foreign consumers will demand the same quantities of the domestic good. For  $\alpha < \frac{1}{2}$ , domestic consumers will always demand relatively more domestic goods than foreign consumers.

Representative consumers in each country receive income from selling their products, from asset holdings, and from transfers of the domestic government. Households then consume, accumulate real money balances, purchase new assets and split savings between money and other assets. In each period  $t$  the economy experiences one of finitely many events  $x_t$ . Let  $h^t$  denote the history of realized states from period zero until period  $t$ , i.e.,  $h^t = \{x_0, x_1, \dots, x_t\}$ . The probability, as of period zero, of any particular history  $h^t$  is  $\pi(h^t)$ . The initial realization  $x_0$  is given.

I assume that capital markets are complete. The consumers of both countries purchase a portfolio of state-contingent home currency denominated nominal bonds at price  $Q(h^t, h^{t+1})$ . Their problem is to maximize:

$$EU = \sum_{t=0}^{\infty} \sum_{h^t} \beta^t \pi(h^t) \left[ u(C(i, h^t)) + m\left(\frac{M(i, h^t)}{P(h^t)}\right) - v(Y(i, h^t), z(h^t)) \right] \quad (2)$$

subject to the sequence of budget constraints:

$$P(h^t)C(i, h^t) + \sum_{h^t} Q(h^t, h^{t+1})b(i, h^t) + M(i, h^t) \leq (1 - \tau)P_H(i, h^t)Y(i, h^t) + M(i, h^t) + b(i, h^t) + TR(i, h^t) \quad (3)$$

where  $P(h^t)$ , is the aggregate price index;  $b(i, h^t)$  are nominal bonds;  $P_H(i, h^t)$  is the price that the household  $i$  charges for its product  $Y(i, h^t)$  at date  $t$ ;  $TR(i, h^t)$  are nominal lump sum transfers from the domestic government to domestic household  $i$  at date  $t$  and  $\tau$  is a proportional income tax.

## 2.2 Consumption Risk Sharing

The first order condition for bond holdings of the domestic consumers is:

$$\beta\pi(h^{t+1}) \left( \frac{u_c(h^{t+1})}{u_c(h^t)} \right) \frac{P(h^t)}{P(h^{t+1})} = Q(h^{t+1}, h^t) \quad (4)$$

A condition analogous to (4) must hold for consumers that hold home currency bonds in the foreign country:

$$\beta\pi(h^{t+1}) \left( \frac{u_c^*(h^{t+1})}{u_c^*(h^t)} \right) \left( \frac{P^*(h^t)}{P^*(h^{t+1})} \right) \left( \frac{e(h^t)}{e(h^{t+1})} \right) = Q(h^{t+1}, h^t) \quad (5)$$

Defining the real exchange rate as:  $q(h^t) = e(h^t)P^*(h^t)/P(h^t)$ , combining (4) and (5) and iterating we have:

$$q(h^t) = \chi \frac{u_c^*(h^t)}{u_c(h^t)} \quad (6)$$

Equation (6) relates real exchange rates and marginal rates of substitution, where  $\chi = u_c(s_0)P^*(s_0)/u_c^*(s_0)P(s_0)$  is a constant, reflecting initial wealth differences. If PPP holds (and this will occur in the model when  $\eta = 1$ ), marginal utilities of consumption are equated up to a constant,  $\chi$ , as agents confront identical commodity prices. In general, movements in the real exchange rate will be reflected in different consumption rates. Hence, even with complete financial markets, when the elasticity of substitution between domestic and foreign goods is different from one, it is not efficient to equalize consumption across countries because PPP does not hold. This property is crucial for understanding the results we obtain in the following sections.



### 2.3 Firms

Production units are imperfectly competitive and, following Calvo (1983), at each point in time each domestic producer is allowed to reset her price with a constant probability, independently of the time elapsed since the last adjustment. There are shocks to the production of the differentiated goods at home and abroad. Producers face domestic and foreign demand for their product, but do not engage in international price discrimination. When a producer receives a signal to change her price, she chooses her new price,  $P_H^n(i, h^t)$ , to maximize:

$$\max_{P_H^n} \sum_{k=0}^{\infty} \sum_{h^{t+k}} (\beta\gamma)^k Q(h^{t+k}, h^t) \{(1-\tau)P_H^n(i, h^t)Y(i, h^{t+k}) - v(Y(i, h^{t+k}); z(h^{t+k}))\} \quad (7)$$

where nominal revenues are discounted by  $Q(h^{t+k}, h^t) = \beta \prod_{j=1}^k \pi(h^{t+j}, h^{t+j-1}) \left(\frac{u_c(h^{t+k})}{u_c(h^t)}\right) \frac{P(h^t)}{P(h^{t+k})}$ , which is the same for all consumers because of complete markets, and  $1 - \gamma$  is the probability that a monopolistic producer faces to reset her price.  $z(h^t)$  and  $z^*(h^t)$  are the domestic and the foreign productivity shocks, which are assumed to evolve according to:

$$\xi_{t+1} = \Gamma\xi_t + \varepsilon_t \quad (8)$$

where  $\xi_t' = [z_t, z_t^*]$ ,  $E_t \varepsilon_{t+1} = 0$ ,  $E_t \varepsilon_t \varepsilon_t' = D$ .

The sellers maximize expected returns from sales revenues, subject to the sequence of demand constraints:

$$Y^d(i, h^{t+k}) = \left(\frac{P_H(i, h^t)}{P_H(h^{t+k})}\right)^{-\theta} [C_H(h^{t+k}) + C_F^*(h^{t+k})] \quad (9)$$

where  $P_H(h^t)$  is the domestic price index and  $C_F^*(h^t)$  is foreign demand for domestic goods. Staggered price setting implies the following expression for the evolution of the domestic price index:

$$P_H(h^t) = [\gamma P_H(h^{t-1})^{1-\theta} + (1-\gamma)P_H^n(h^t)^{1-\theta}]^{\frac{1}{1-\theta}} \quad (10)$$

where the second term comes from the firm's optimality condition:

$$P_H^n(i, h^t) = \frac{\theta \sum_{k=0}^{\infty} \sum_{h^{t+k}} (\gamma\beta)^k Q(h^{t+k}, h^t) v_y(Y^d(i, h^{t+k}), z(h^{t+k})) Y^d(i, h^{t+k})}{(\theta - 1)(1 - \tau) \sum_{k=0}^{\infty} \sum_{h^{t+k}} (\gamma\beta)^k Q(h^{t+k}, h^t) Y^d(i, h^{t+k})} \quad (11)$$

The terms of trade, i.e., the price of domestic relative to foreign goods, denoted by  $S(h^t)$ , equals the ratio of foreign to home prices  $P_F(h^t)/P_H(h^t)$ .

## 2.4 The Flexible Price Equilibrium

The flexible price equilibrium in loglinear form is characterized by the following relationships:

$$s_t^n = v_s(z_t - z_t^*) \quad (12)$$

$$c_t^n = \left[ \frac{1 - 2\alpha}{\sigma} + \frac{\alpha(1 + \omega\psi_s)}{\sigma + \omega} \right] v_s z_t + \frac{\alpha(1 + \omega\psi_s)}{\sigma + \omega} v_s z_t^* \quad (13)$$

where  $v_s = \left[ \frac{(\sigma + \omega)(1 - 2\alpha)}{\sigma} + 2\alpha(1 + \omega\psi_s) \right]^{-1}$ ,  $\zeta = -\frac{v_{yz}}{Y v_{yy}}$ ,  $\psi_s = [2\eta(1 - \alpha) - \frac{(1 - 2\alpha)}{\sigma}]$  and the superscript 'n' natural (flexible price) variables.

It is easy to verify that due to risk sharing consumption across countries will commove following a positive productivity shock, independently of its origin. The terms of trade, on the other hand, are affected by the relative size of the two productivity shocks. For example, an increase in productivity in the home country is offset in equilibrium by a depreciation of the terms of trade which works as an insurance for the consumers of the foreign country. The effect of country-specific productivity shocks on both variables depends on the elasticity of substitution between home and foreign goods,  $\eta$ ; the intertemporal elasticity of substitution,  $1/\sigma$ ; the labor supply elasticity  $1/\omega$ ; and the degree of openness of the economy,  $\alpha$ .

In particular, when there is no home bias in consumption ( $\alpha = \frac{1}{2}$ ), domestic and foreign shocks affect equally consumption:  $c_t^n = \frac{(1 + \omega\psi_s)}{2(\omega + \sigma)} v_s \zeta (z_t + z_t^*)$ . However, when  $\alpha < 1/2$ , changes in  $z_t$  will increase domestic consumption more than foreign consumption. Hence, asymmetric productivity shocks produce sizeable differences in the responses of consumption across countries.

## 2.5 The Rigid Price Equilibrium

After loglinearizing, the optimality conditions can be collapsed into 3 equations for the domestic economy (the equations for the foreign country are analogous)<sup>1</sup>.

$$c_t = E_t c_{t+1} - \frac{1}{\sigma}(\widehat{R}_t - E_t \pi_{Ht+1}) + \frac{\alpha}{\sigma} E_t \{\Delta s_{t+1}\} \quad (14)$$

$$(\widehat{R}_t - E_t \pi_{Ht+1}) - (\widehat{R}_t^* - E_t \pi_{Ht+1}^*) = E_t \{\Delta s_{t+1}\} \quad (15)$$

$$\pi_{Ht} = \beta E_t \pi_{Ht+1} + \kappa_c (c_t - c_t^n) + k_s (s_t - s_t^n) \quad (16)$$

where  $k = \frac{1-\gamma}{\gamma}(1 - \gamma\beta)$ ,  $k_c = k(\frac{\sigma+\omega}{1+\theta\omega})$ ,  $k_s = \frac{k\alpha(1+\omega\psi_s)}{1+\theta\omega}$  and  $\pi_{Ht}$  denotes domestic inflation.

Equation (14) states that aggregate demand depends on nominal interest rates as well as expectations of domestic inflation and terms of trade changes. In a closed economy the last term is absent. Equation (15) is the real interest parity condition relating movements of the real interest rate differential to expected variations in the relative prices.

Equation (16) represents an aggregate supply curve. In this equation domestic inflation rate depends on the expectations of future price setting and on the deviations of the terms of trade and domestic consumption from their flexible price values. These last two terms enter the specification because they determine the path of real marginal costs in the economy. In particular, terms of trade influence domestic inflation because they indirectly contribute to the real marginal costs. Producers set domestic prices but they minimize costs discounting wages with CPI prices. With no international price discrimination CPI prices are directly affected by changes in relative prices. However, as the economy becomes autarkic, the importance of relative prices for domestic inflation declines ( $k_s \rightarrow 0$  as  $\alpha \rightarrow 0$ )

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<sup>1</sup>Lower case variables denote the percentage deviations from respective steady state values and variables with stars denote foreign variables.

Hence, the economy is represented by the home aggregate supply equation (16) and its foreign analogue, the domestic and foreign aggregate demand equations (14), the real interest parity condition (15), and the law of motion for the exogenous productivity shocks (8). To characterize the equilibrium completely we next describe how monetary policy is conducted.

### 3 Monetary Policy

Monetary policy may have different objectives since the equilibrium is suboptimal both because of the market power distortion and of nominal rigidities. I assume that employment is subsidized in equilibrium so as to neutralize the monopolistic competition distortion. This is achieved by setting  $\tau = -(\theta - 1)^{-1}$ . I also assume that the liquidity services of money are small. By doing so, I eliminate the monetary distortion that would make the Friedman rule optimal. These modifications make the flexible price equilibrium efficient<sup>2</sup>.

Optimal monetary policy entails the optimization of a social objective function, given the aggregate constraints in the economy. A natural welfare criterion to evaluate the losses is the discounted sum of the utility flows of the households. Rotemberg and Woodford (1998) used this criterion for closed economy problems. The arguments of the central bank's objective in an open economy are different from those of a closed economy because variations in the relative prices affect consumption across countries differently. After tedious algebraic manipulations it is possible to show that the utility of the

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<sup>2</sup>Some authors have suggested the introduction of distortionary taxation (subsidies) to produce the right incentives when central banks use the terms of trade strategically (See for example, Benigno and Benigno (2002)). The competitive distortion, however, results because prices are sticky in the short-run. Under flexible prices, monetary policy is ineffective and central banks cannot distort allocations via manipulation of the terms of trade. Hence, any tax or subsidy that does not completely offset the distortions associated with monopolistic competition will not produce an optimal allocation.

representative consumer in each country can be approximated by:

$$W_t^i = E_0 \left\{ \Phi \sum_{t=0}^{\infty} \beta^t L_t^i \right\} \text{ for } i = H, F$$

$$\text{with } L_t^H = \{ \phi_c (c_t - c_t^n)^2 + \pi_{Ht}^2 + \phi_s (s_t - \delta s_t^n)^2 + \phi_{sc} (s_t - \delta s_t^n) (c_t - c_t^n) \}$$

$$\text{and } L_t^F = \{ \phi_c (c_t^* - c_t^{*n})^2 + \pi_{Ht}^{*2} + \phi_s (s_t - \delta s_t^n)^2 - \phi_{sc} (s_t - \delta s_t^n) (c_t^* - c_t^{*n}) \} \quad (17)$$

$$\text{where } \Phi = -1/2u_c C \frac{\gamma}{(1-\gamma)(1-\gamma\beta)} \theta (1 + \theta\omega), \phi_c = \frac{(1-\gamma)(1-\gamma\beta)}{\gamma\theta} \frac{\sigma+\omega}{1+\theta\omega},$$

$$\phi_s = \frac{(1-\gamma)(1-\gamma\beta)}{\gamma\theta} \frac{\alpha^2 \psi_s^2 (1+\omega)}{(1+\theta\omega)}, \phi_{sc} = \frac{(1-\gamma)(1-\gamma\beta)}{\gamma\theta} \frac{\alpha \psi_s (1+\omega)}{(1+\theta\omega)}, \delta = \frac{(\sigma+\omega)\psi_s}{1+\omega\psi_s}$$

Equation (17) differs from the standard welfare criterion used in a closed economy in several ways. As in a closed economy, the welfare criterion for independent central banks depends on the deviations of consumption from their flexible price levels and on the variability of inflation. However, an independent central bank is also concerned with the variance of the deviations of the terms of trade from an optimal level and its covariance with domestic consumptions. Independent monetary authorities in an open economy do not seek, in general, to replicate the flexible price allocation.

An internationally asymmetric welfare distribution might, in fact, be induced by either a depreciation above the flexible price level or by making domestic demand covary with the deviations of the terms of trade. Note that if  $\delta = 1$ , central banks in the two countries will maximize welfare by setting consumption and terms of trade to their flexible price levels. However, the coefficient  $\delta$  crucially depends on two parameters of the model: the intertemporal elasticity of substitution,  $1/\sigma$ , and the elasticity of substitution between home and foreign goods,  $\eta$ . Independently of  $\alpha$ ,  $\delta = 1$  whenever  $\eta = \sigma = 1$ .

An increase in the productivity in the home country depreciates the terms of trade and, as a result, demand for home goods increases, and this increases domestic inflation. Whenever the international demand elasticity is equal to one, consumption is equalized across countries because of risk

sharing and, as a result, domestic consumption increases less than output in equilibrium and this decreases domestic inflation <sup>3</sup>. When  $\sigma = 1$  the risk sharing effect cancels out with the terms of trade effect, there are no externalities from movements in the terms of trade on domestic inflation, and thus no incentives to use the former to strategically increase domestic welfare. Note also that when the two countries are economically independent, the additional terms disappear ( $\alpha \rightarrow 0$ ,  $\phi_s$ , and  $\phi_{sc} \rightarrow 0$ ), since no reallocation of resources across countries results from asymmetric shocks.

Some authors have argued that in an open economy it is possible to derive a second order approximation of the consumer's utility, which can be used for policy evaluation in log-linear models, only when the international and intertemporal demand elasticities are equal (see e.g. Benigno and Benigno (2002), Gali and Monacelli (2002)). These parameter restrictions are needed because they allow for an exact relationship between output, consumption and relative prices that can be used into the first order terms appearing in the welfare approximation.

The welfare criterion I derive is valid for all possible values of these elasticities. The approximation used omits a term in the square of the terms of trade. Since the omitted terms are independent of policy and since in each of the three regimes the same term is omitted, the ranking of welfare across regimes is valid. Furthermore, while the magnitude of welfare costs in each of the regime might not be accurate, this term is zero whenever  $\alpha = 1/2$ , or  $\alpha$  is small<sup>4</sup>.

Using central banks' objective functions (17) I will analyze the properties of the equilibrium under alternative hypotheses regarding the way monetary policy is conducted. I will consider three alternatives: (a) Cooperative, (b) Non-cooperative monetary policy and (c) Monetary union.

I will assume that the policymakers can choose the entire future (state-

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<sup>3</sup>See also, Clarida, Gali and Gertler (2002).

<sup>4</sup>See Appendix 2 for details.

contingent) evolution of the control variables, once and for all, at date zero. In other words, I am only considering policies *under commitment*. The assumption of commitment is important, since the private sector expectations about the evolution of prices affect the forward looking terms in equations (14) - (16). In general, the optimal plan is not time consistent, but there are instances when it delivers a better outcome than a time-consistent plan that results from optimization under discretion (see, e.g. Woodford (1999)).

## 4 Calibration

Because the problems solved by the central banks under the different policy regimes do not have closed form solutions, I resort to simulations to compare the welfare outcomes of different arrangements. I calibrate the parameters of the model using the United States and European economies to provide a realistic flavour to the comparison. Time is taken to be quarters and the parameters used are reported in Table 1.

I set the discount factor  $\beta = 1.03^{-1/4}$ , so as the annual real interest rate equals 4%. The parameter  $\theta$ , the elasticity of substitution among differentiated goods is set equal to 7.88. Since in the steady state  $\theta$  equals the mark-up of prices over marginal costs, this value implies a mark-up of 14%. The parameter  $\omega$  measures the curvature of the disutility of labor. Empirical evidence suggests that wage elasticities lie in the interval  $[0.1, 1]$  (see Gali, Gertler and Lopez-Salido (2002)). I set the elasticity of labor supply equal to 0.3, which is smaller than the one used in Rotemberg and Woodford (1998) ( $\omega = 0.4633$ ) because their value implies a labor supply which is very elastic. The degree of price stickiness, measured by  $\gamma$ , is set equal to 0.75, which implies an average frequency of price adjustment of four quarters.

The coefficient of relative risk aversion  $\sigma$  is usually assumed to take values in the interval  $[1, 6]$ , while the elasticity of substitution between home and foreign goods is estimated between  $[1, 2]$  (see Chari et al. (1998)). In the

benchmark preferences specification I set  $\sigma = 2$  and  $\eta = 1.5$ , and I perform a sensitive analysis to study how the gains from cooperation change for different values of these elasticities.

To set  $\alpha$ , note that in the symmetric steady state  $\alpha = C_F/C_H$ , the share of imported to domestic goods. The value of this parameter does not differ significantly across Europe and the US. According to Chari et al. (1998), imports from Europe to US are roughly 2.0% of GDP, while for Europe the corresponding number is around 2-4% according to Eurostat data. Thus, the assumption of symmetry appears reasonable. In the benchmark case, I set the index of openness equal to 0.2, and perform a variety of sensitivity experiments to access how results change when this parameter varies. Finally, the parameters of the productivity process are those obtained from Backus, Kehoe and Kydland (1992).

## 5 International Monetary Policy Regimes

### 5.1 Cooperative Monetary Policy (CO)

Monetary policy cooperation is modeled as the case in which policy decisions are delegated to a supranational monetary institution which has the objective of maximizing a weighted average of the welfare of the consumers in each country. Since the two countries are symmetric, I constrain the weights to be equal. Intuitively, consumers should be at least as well off when the central banks cooperate as when they do not. Cooperating policymakers can always implement the non-cooperative outcome by choosing their non-cooperative strategies. Since that outcome is feasible under cooperation, rational policymakers will never choose anything worse.

The problem of the central authority is to choose stochastic processes for  $\{c_t, \pi_{Ht}, \widehat{R}_t, c_t^*, \pi_{Ht}^*, \widehat{R}_t^*, s_t\}$  to maximize the weighted average of the welfare in the two countries, as a function of the information set  $I_t$ , which includes all the history and information about the evolution of the exogenous



disturbances  $z_t$  and  $z_t^*$  and subject to the constraints given by (8) and (14)-(16), in the two countries at all dates  $t \geq 0$ . Formally the problem is,

$$\max_{\{c_t, \pi_{Ht}, \hat{R}_t, c_t^*, \pi_{Ht}^*, \hat{R}_t^*, s_t\}} E_0 \left\{ \Phi \sum_{t=0}^{\infty} \beta^t \left\{ \frac{1}{2} L_t^H + \frac{1}{2} L_t^F \right\} \right\},$$

Substituting for  $L_t^H$  and  $L_t^F$  results in:

$$\max E_0 \left\{ \frac{\Phi}{2} \sum_{t=0}^{\infty} \beta^t \phi_c [(c_t - c_t^n)^2 + (c_t^* - c_t^{*n})^2] + (2\phi_s + \phi_{sc} \frac{(1-2\alpha)}{\sigma}) (s_t - s_t^n)^2 + \pi_{Ht}^{*2} + \pi_{Ht}^2 \right\}$$

The social planner internalizes the externality due to the terms of trade movements and seeks to replicate the flexible price allocation. Such an objective translates into movements of the terms of trade that mimic those obtained under the flexible price equilibrium.

The solution to the problem is:

$$(1 - \Gamma L)q_{t+1} = (1 - ZL)\xi_{t+1}$$

where  $q_t = \{c_t, \pi_{Ht}, \hat{R}_t, c_t^*, \pi_{Ht}^*, \hat{R}_t^*, s_t, \phi_t\}$ ,  $\phi_t = \{\phi_{1t}, \phi_{2t}, \phi_{1t}^*, \phi_{2t}^*\}$  is the vector of deviations of the Lagrange multipliers from their respective steady state values and  $\xi_t = \{z_t, z_t^*\}$ . The multipliers  $\phi_{1t}, \phi_{2t}, \phi_{1t}^*, \phi_{2t}^*$  give the shadow value of relaxing the aggregate demand and the aggregate supply constraints home and abroad. Since the social planner does not inherit any initial values for his choice variables and the aggregate constraints depend on expectations of the choice variables, a necessary condition for the optimization under commitment is  $\phi_{10} = \phi_{20} = \phi_{10}^* = \phi_{20}^* = s_0 = 0$ .

The only distortion in the economy is the stickiness of prices and the resulting inertia in relative prices. Since the social planner has two instruments available to correct for these distortions (i.e., the nominal interest rate and the nominal exchange rate), she can implement the flexible price allocation, which is Pareto optimal. Since the first best is attained in the cooperative solution, the welfare of the consumers when the two policymakers cooperate

can be used as a benchmark for comparing the outcomes of the other policy regimes. For this purpose I calculate the index of utility losses in terms of the equivalent consumption decreases associated with suboptimal equilibria (OCU, optimal consumption units in percentage terms).

Figures 1 and 2 present the responses of the domestic macroeconomic variables to a domestic and a foreign productivity shock, respectively (the responses of the foreign variables are similar). It is easy to verify that the impulse response functions of the cooperative and the flexible price solutions are identical. A positive domestic productivity shock reduces inflation at home. Since the terms of trade depreciate, demand for domestic goods rises and thus expectations for future inflation. The movements in the nominal interest rates are such that the latter effect balances the effect of the productivity on inflation. As a result, inflation hardly moves in equilibrium.

Gali (1999) has shown that in response to a positive productivity shock, labor productivity rises more than output and he argues that this fact can be explained in the context of a closed economy general equilibrium model with monopolistic competition and nominal rigidities. However, in an open economy this pattern can be replicated without the need of nominal rigidities. From Figure 1 we see that output reacts less than the change in technology while there is a negative movement in employment. These imply that labor productivity rises more than output.<sup>5</sup> This outcome, however, depends on the labor supply elasticity and on the value of  $\sigma$ . The demand for labor depends on the domestic price index, while the supply of labor depends on the aggregate price index. Under flexible prices, a positive domestic productivity shock increases labor demand and real wages. On the other hand, because of an income effect, the supply of labor decreases. In the bench-

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<sup>5</sup>Collard and Dellas (2001) suggest that labor productivity responses can be replicated in an RBC model as long as trade elasticities fall short of unity and the degree of openness is sufficiently high. Here, I can generate negative conditional correlation between productivity and employment without having to assume low elasticities of substitution between home and foreign goods.

mark specification where the labor supply is steep these movements lead to a reduction in domestic employment.

## 5.2 Non-Cooperative Monetary Policy (NC)

In a non-cooperative Nash equilibrium, each monetary authority maximizes the expected utility of its own consumers subject to the domestic economy constraints and taking as given the policy of the foreign policymaker. The problem of the domestic policymaker is therefore:

$$\max_{\{c_t, \pi_{Ht}, s_t\}} E_0 \Phi \sum_{t=0}^{\infty} \beta^t \{ \phi_c (c_t - c_t^n)^2 + \pi_{Ht}^2 + \phi_s (s_t - \delta s_t^n)^2 + \phi_{sc} (s_t - \delta s_t^n)(c_t - c_t^n) \} \quad (18)$$

subject to (8) and (14)-(16), the exogenous process for the productivity shocks and given  $c_t^*$ ,  $\pi_{Ht}^*$ , and  $\hat{R}_t^*$ . Since the foreign policymaker behaves symmetrically, her objective is given by:

$$\max_{\{c_t, \pi_{Ht}, s_t\}} E_0 \Phi \sum_{t=0}^{\infty} \beta^t \{ \phi_c (c_t^* - c_t^{*n})^2 + \pi_{Ht}^{*2} + \phi_s (s_t - \delta s_t^n)^2 - \phi_{sc} (s_t - \delta s_t^n)(c_t^* - c_t^{*n}) \} \quad (19)$$

The two central banks place opposite weights on the expected relative price depreciation and the covariance between domestic spending and the deviations of the terms of trade from its domestically optimal value. To understand the incentives that central banks face consider the case when terms of trade spillovers matter (i.e.  $\delta \neq 1$ ). Take  $\eta = 1$  and  $\sigma > 1$ , for example. Here, the risk sharing effect dominates the terms of trade effect and increases of the terms of trade above potential decrease domestic inflation. When  $\eta > 1$  and  $\sigma = 1$ , a worsening of the terms of trade generates large consumption swings towards domestic goods, so relative revenues and consumption of the domestic consumers increase. In both cases the domestic authority would want to depreciate the terms of trade in excess of what the flexible price equilibrium would require. If  $\eta$  and/or  $\sigma < 1$ , the opposite is true and the monetary authority seeks to limit terms of trade

movements. Finally, when  $\eta = \sigma = 1$ , there are no spillovers from terms of trade movements and thus no incentives to deviate from the flexible price allocation.

From Figure 1 and 2 (where  $\eta, \sigma > 1$ ), we see that domestic consumption and output increase more in the non-cooperative equilibrium, while consumption in the foreign country increases less than in the flexible price equilibrium and output falls. The competition policy of the two policymakers does not allow minimization of inflation variability in the two countries. Domestic inflation increases and foreign inflation falls because of the consumption switching towards domestic goods. While under cooperation domestic and foreign employment fall independently of the origin of the shock, in the non-cooperative equilibrium, domestic employment increases and foreign employment falls to satisfy the swing in consumption towards domestic goods. If the domestic central bank internalized the effects of the terms of trade movements on domestic employment, it could increase domestic welfare by simultaneously increasing consumption and leisure.

### 5.3 Monetary Union (MU)

One way to accomplish some of the benefits of policy cooperation without delegating the optimization problem to a supranational planner is through the establishment of a monetary union. In this case, the problem of the central bank is similar to the problem faced by the institution of the section 5.1 with the only difference that in a currency area the nominal exchange rate is fixed. Thus, monetary union can be viewed as "cooperation with one instrument only" - the union wide nominal interest rate.

In a monetary union the fixity of the nominal exchange rate coupled with the rigidity in prices introduces an additional distortion in the economy: the inertia of relative prices. Notice that there is a trade-off between price stickiness and relative price distortions, since attempts to neutralize price stickiness, setting domestic inflation equal to zero, increase the distortions

due to the inertia of the terms of trade. In the optimal allocation domestic prices are stabilized and consumption and terms of trade are equal to their flexible price levels. In a monetary union, these three conditions cannot be simultaneously satisfied (see also Figure 1 and 2). Low inflation variability implies sluggish relative prices which in turn result into an inefficient reaction of output in response to foreign disturbances and thus higher consumption variability. The nominal interest rate is also more variable, since it is the only instrument the Central Bank can use for accommodating productivity shocks. A positive productivity shock decreases the union-wide nominal interest rate independently of its origin. Consequently, domestic and foreign consumption and output comove, while employment is countercyclical.

## **6 How large are the gains from Cooperation?**

The analysis of the previous section reveals that there are possibly gains from cooperation, since independent monetary policies might have an incentive to use the terms of trade strategically in order to increase domestic welfare. Obstfeld and Rogoff (2001) showed that these gains are negligible even when one departs from the assumption of logarithmic utilities in a general equilibrium model with wage rigidities and tradable and non tradable goods. Corsetti and Pesenti (2001b) illustrated the same point for a general equilibrium sticky price model with consumer currency pricing and complete exchange rate pass through. However, both results are based on the assumption of unitary international demand elasticities. Benigno and Benigno (2002) argue that the value of the international elasticity of substitution is crucial in determining the welfare gains from cooperation and conclude that the conditions under which non-cooperative and cooperative equilibrium coincide are "special." Surprisingly, these "special" conditions turn out to be exactly the conditions under which it is optimal to replicate the flexible price allocation in the present framework.

In this section I characterize the pattern of the gains from coordination when key parameters of the model are varied within a reasonable range.

### **6.1 The intertemporal and intratemporal elasticities of substitution**

The values for the intertemporal and international demand elasticities are crucial for determining whether the social planner's and the independent banks' objectives coincide. Their magnitude determines whether there is interdependence between the two countries from a stabilization point of view. When there is no such interdependence the cooperative equilibrium coincides with the non-cooperative one and there are no gains from coordination. However, when such interdependence exists, independent monetary authorities do not internalize these externalities and there are losses due to policy competition.

The question of interest here is how large the gains from cooperation are when we depart from the assumption of unitary intertemporal and international elasticities. I calculate the welfare costs of policy competition for both the case of home bias and no home bias in consumption. In Figure 3 I plot the costs from non-cooperation for the case of no home bias in consumption. As it is apparent, the gains from cooperation are zero locally around  $\eta = \sigma = 1$ , while the increase whenever we depart from these points and reach their maximum value for  $\eta = 6$  and  $\sigma = 6$ . Empirical evidence suggests values for  $\sigma$  between 3 and 10 (See, Gali, Gertler and Lopez-Salido (2002)) and values for  $\eta$  in the interval [1,2] for Europe and the US (See, Chari, Kehoe and McGrattan (2000)) are reasonable. Within these bounds the largest loss from non-cooperation is about 0.51 percent of steady state consumption units - not a negligible number.

## 6.2 The degree of openness

In the previous subsection we have assumed no home bias in consumption. However, this is an extreme assumption which is somewhat contradicted when we look at the data. Here I analyze how the losses from non-cooperation change for different degrees of home bias in consumption. Since in the steady state the degree of home bias is closely related with the degree of openness, I interpret my results as produced by changes in the degree of openness of the economies. In Figure 4 I present how the degree of openness affects the losses from policy competition for different values of the intertemporal and international demand elasticity: in general, the costs of non cooperation increase with the degree of openness of the economy. For  $\alpha = 0.02$ , they are close to zero independently of the values of  $\eta$  and  $\sigma$ ; they increase for  $\alpha = 0.15$  and they reach their maximum for  $\alpha = 0.5$ . For the empirically relevant values of  $\eta$  and  $\sigma$ , when  $\alpha$  is reduced to 0.15, the maximum welfare loss drops from 0.51 to 0.35 percent of optimal consumption units. For the calibrated value for the degree of openness of the European and the US economies ( $\alpha = 0.02$ ) this value is only 0.06 percent of steady state consumption.

Intuitively, for relatively closed economies the gains from cooperation must be small. With the welfare criterion used, as the degree of openness approaches zero the terms concerning relative prices disappear and, as a result, optimal policy resembles the one of a closed economy. In other words, when the two economies are almost autarkic, the reallocation of resources in equilibrium is small and the gains from cooperation become negligible.

## 6.3 The correlation of shocks

To complete the analysis I have also considered whether gains from cooperation change with the correlation of shocks. In the benchmark specification the two shocks are positively correlated. When we assume that the shocks between the two countries are perfectly correlated the costs of non coop-

eration are zero whatever the intertemporal and intratemporal elasticities and of the degree of openness of the economies are. (See also Obstfeld and Rogoff (2001)).

A negative correlation between the productivity shocks in the two economies increases the losses from policy competition. For example, if we assume that  $\text{Corr}(z, z^*) = -0.258$ , then losses from cooperation increase for all values of  $\sigma$  and  $\eta$ , away from the ridge of  $\eta = \sigma = 1$ , by approximately 10% and they reach a maximum for the feasible range of parameter values of 0.60 percent of optimal consumption units. Losses from non-cooperation are negatively related to the degree of correlation between domestic and foreign shocks. This is because the additive asymmetry of negative correlated shocks increases the incentives of policymakers to deviate from the flexible price allocation when the terms of trade cannot automatically pool idiosyncratic shocks.

#### **6.4 The labor supply elasticity**

Given the important role of the labour markets in determining the size of the externalities due to misallocation of resources when  $\eta\sigma \neq 1$ , and the empirical and theoretical controversy over the exact value of  $\omega$ , I have also examined whether the gains from cooperation change substantially for higher values of the (Frisch) wage elasticity of the labor supply.

The welfare costs of policy competition are highly sensitive to this parameter. For small values of  $\omega$ , welfare costs are larger than in the benchmark specification. For example, for the specification of Rotemberg and Woodford (1998) with  $\omega = 0.4633$  welfare costs within the region of feasible parameter values reach a maximum, when  $\sigma = 6$  and  $\eta = 2$ , of 2.5% of optimal consumption units. This is because low values of  $\omega$  imply that the labor supply schedule is flat and the increase in labor after a positive productivity shock is more pronounced. As a result, the lower  $\omega$  the higher the the cost of labor and thus, the cost of policy competition.



## 7 Can a Monetary Union Improve upon Non-cooperation?

For  $\eta = \sigma = 1$  a monetary union is clearly suboptimal, since independent monetary authorities can achieve the optimal solution without fixing the exchange rate. As in Obstfeld and Rogoff (2001), unless domestic and foreign shocks are perfectly positively correlated, fixing the exchange rate is never optimal. Nevertheless, a monetary union can be preferable to policy competition when the two productivity shocks are not perfectly correlated and the intertemporal and intratemporal elasticity of substitution are in the feasible range. In Figure 5, I plot the relative gains obtained in a monetary union for the benchmark specification. A monetary union is beneficial when non-cooperation is not. Contrary to the case of non-cooperation, the costs of a monetary union fall as the elasticity of substitution between home and foreign goods increases, while they increase with  $\sigma$ . As mentioned, a monetary union is associated with costs due to the inefficient movements of the terms of trade. However, when home and foreign goods have a high degree of substitutability, small changes in the terms of trade can induce large consumption switches and consequently, the loss of the exchange rate instrument becomes less important. On the other hand, when  $\sigma$  is low, consumers prefer to distribute consumption equally across states and across time, while when  $\sigma$  is high, they want to consume more when domestic prices are low. Consequently, for low values of  $\sigma$  the costs of monetary union will tend to be higher.

In Figure 6, I plot the costs of monetary union versus the costs from policy competition. For values of  $\sigma$  and  $\eta$  larger than 2, monetary union produces lower costs and the relative gain increases with  $\eta$ . The relative gains of a monetary union increase with the degree of openness of the economy (Figure 6 is plot for the case of  $\alpha = 0.5$ ). For low  $\alpha$  a central bank cannot induce large consumption switches with small changes in the terms of trade and the optimal reallocation of resources cannot be achieved. How-

ever, even in the case of home bias in consumption there are parameter values for which monetary union is preferable to policy competition.

The relative gains of a monetary union also depend on the degree of price rigidity. Other things equal, a higher degree of price rigidity implies a higher inertia in relative prices and higher welfare costs from the inefficient reallocation of resources for the members of a monetary union. Finally, the ranking between non-cooperation and monetary union is quite robust to the different specification of the labor supply elasticity and the correlation between home and foreign productivity shocks.

The prediction of the model that a monetary union can improve upon non-cooperation is somewhat surprising, given that, for example, Obstfeld and Rogoff (2001), Corsetti and Pesenti (2001b), Devereux and Engel (2000) have found insignificant gains from cooperation in similar models. The results I obtain are similar to those produced in the optimum currency area literature, but the mechanics leading to this outcome are different. Mundell (1961) argued that the benefit of a common currency area lies in minimizing transaction costs and in facilitating the flow of information about relative prices. The offsetting force was that fixed exchange rates entailed a loss of independent monetary policies. In the present framework, a common currency is beneficial when there is enough substitutability between home and foreign goods which can correct for the inertial movements of the terms of trade due to the fixity of exchange rates and the rigidity of prices. In this case the allocation of resources across regions in a monetary union are closer to their efficient counterparts and inflation is more stable.

Cooperation between ECB and the FED produce negligible gains. Would the same result hold if we ask whether UK should join the EMU? The answer is different in this case, because of the strong trading links between the two areas. In this case, not only cooperation will be beneficial, but gains are also recorded when a single monetary union is created. Given the trading links between the two economic areas and assuming that the international

and intertemporal elasticity of substitution are the same in both areas, we find that adoption of the Euro will increase welfare approximately by 0.1 percent.

## 8 Concluding Remarks

This paper has studied the sources of conflict between the monetary policy objectives of two large economies and the extent to which different types of international policy arrangements may help to overcome the sub-optimality resulting from decentralized, non-cooperative decisions. I show that the social planner will always want to replicate the flexible price allocation by setting domestic inflation equal to zero in both countries and in all times. Independent monetary policies, on the other hand, seek to replicate the flexible price allocation only under special conditions. For values of  $\eta$  and  $\sigma$  in the neighborhood of  $\eta = \sigma = 1$ , the gains from cooperation are negligible. However, there are empirically reasonable parameter values for which significant gains from cooperation can be generated.

Non-cooperation implies welfare losses because of the presence of beggar-thy-neighbor and beggar-thyself effects. The magnitude and nature of these effects depends crucially on the international demand and intratemporal elasticities. For given values of these elasticities, the welfare costs from non-cooperation increase with the degree of openness of the economy. As the economy becomes autarkic, the short run adjustment role of the nominal exchange rate is reduced and consumer prices are almost unresponsive to exchange rate changes. Moreover, the costs of non-cooperation are negatively related to the correlation between home and foreign productivity shocks and to the inverse of the labor supply elasticity.

Fixing the exchange rate introduces an additional distortion in the economy, the inertia of the terms of trade, that does not allow the optimal reallocation of resources to be achieved. The adoption of a common currency has

the potential of reducing the welfare costs of monetary policy competition when the economies are open to trade, relatively flexible, and when home and foreign goods are highly substitutable. As long as trade interdependencies between Europe and the US are as small as those experienced in the last 50 years, cooperation between the ECB and the Fed will produce little welfare gain. This might not be true however when considering e.g. the UK and the Euro area economies.

Finally, this paper has focused on the design of optimal monetary policy under commitment. The assumption that the policymakers can commit to policy before prices are set could impart a bias on the estimates on the potential gains from cooperation. On the one hand, setting policy in advance implies that the cooperative institutional arrangements have no independent impact on expectations within the domestic economies. Since the analysis precludes such benefits, it might understate the scope for international policy cooperation. On the other hand, the ability to make commitments could aggravate non-cooperation problems of the type described by Rogoff (1985). In this case, the paper could overstate the potential benefits of international policy cooperation. For these reasons, commitment should be an endogenous outcome of the model, and of the arrangements among countries. Future research studying the conditions under which this may occur may improve our understanding of the interactions existing among open economies.

<b>Table 1: Benchmark Parameter values</b>		
Parameter	Description	Value
$\beta$	Discount factor	$1.03^{-1/4}$
$\sigma$	Relative Risk aversion coefficient	2
$\eta$	Elasticity of substitution between home and foreign goods	1.5
$\theta/\theta-1$	Gross steady state mark-up	1.14
$1-\alpha$	Home bias in consumption	0.8
$1/\omega$	Elasticity of labor supply	0.3
$\gamma$	Probability that a firm will be unable to change its price	0.75
Technology shocks	$\Gamma = \begin{bmatrix} .906 & .088 \\ .088 & .906 \end{bmatrix}$ , and $\text{var}(z) = \text{var}(z^*) = 0.00852$	$\text{Corr}(z, z^*) = .258$

Figure 1: Impulse Responses to a Domestic Productivity Shock

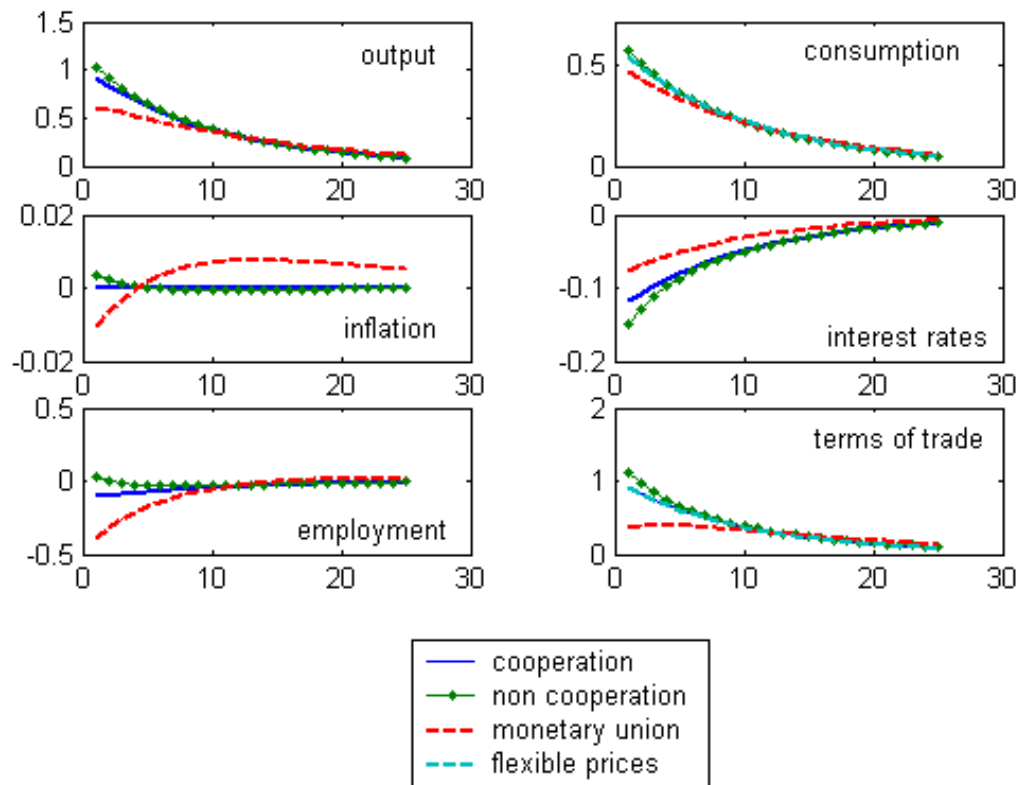


Figure 2: Impulse Responses to a Foreign Productivity Shock

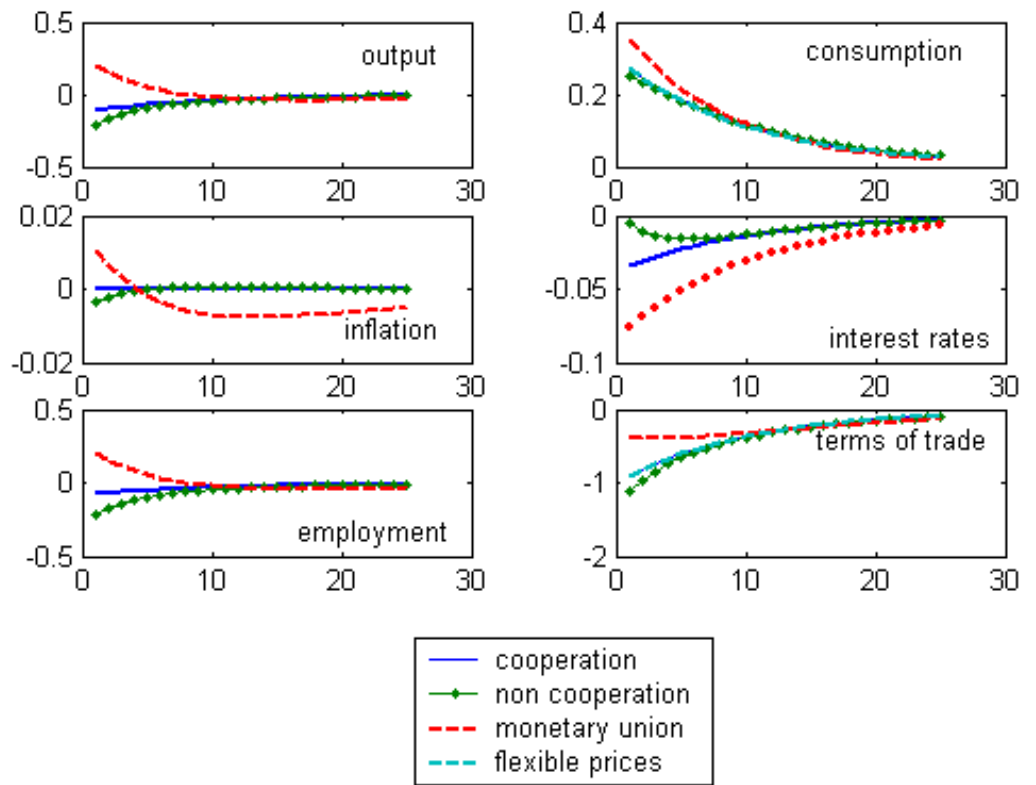


Figure 3: The costs of non-cooperation

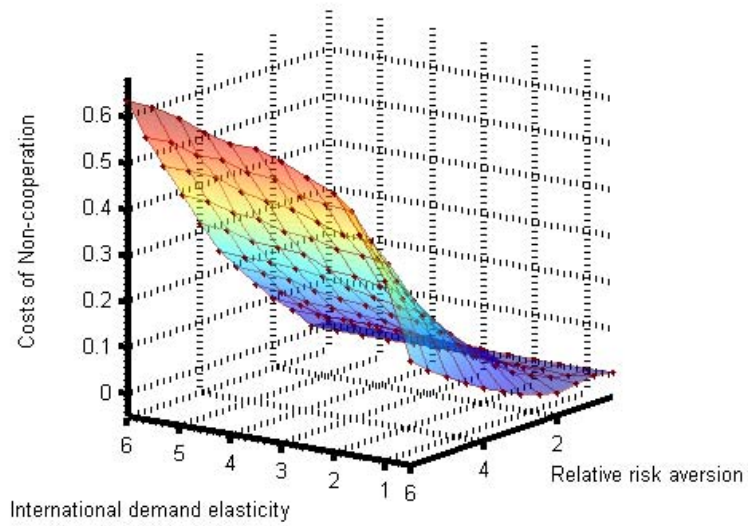
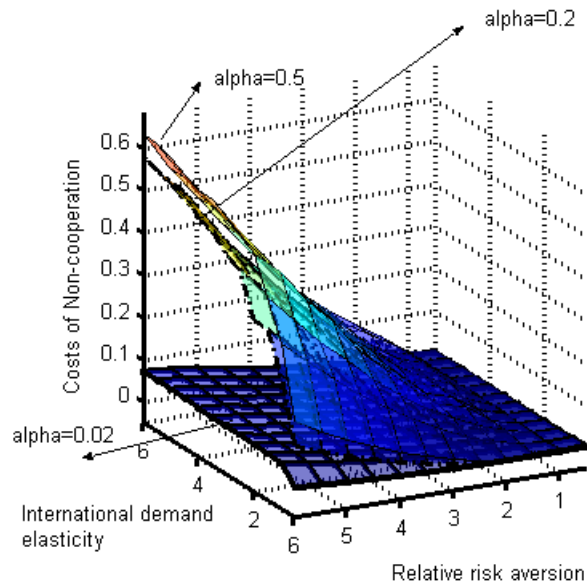
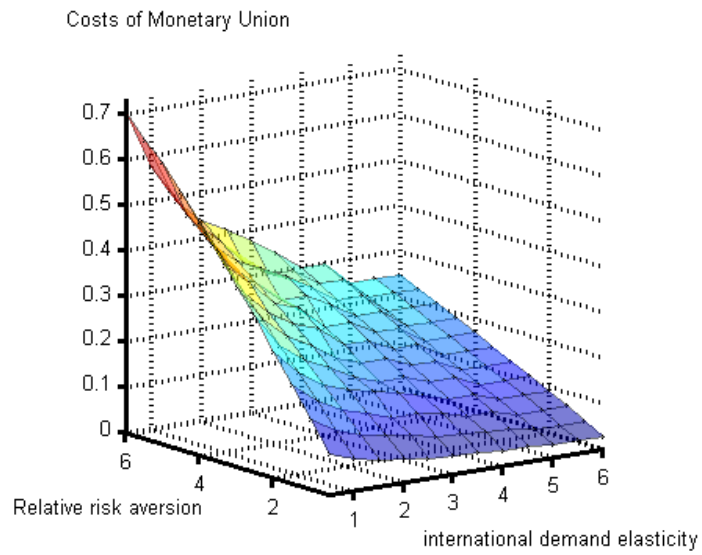


Figure 4: The costs of non-cooperation and the degree of openness

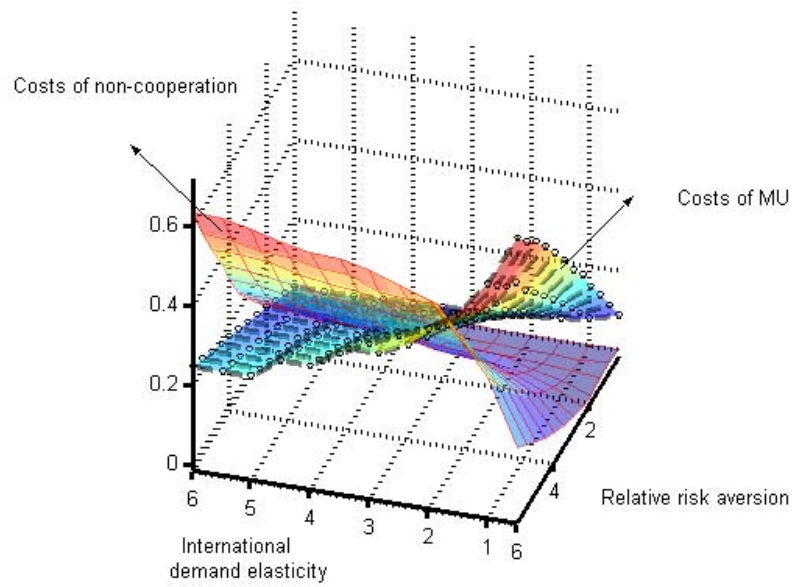




**Figure 5: The Costs of Monetary Union**



**Figure 6: Monetary Union versus Non-Cooperation**



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