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Can Conservatism Be Counterproductive? Delegation and Fiscal Policy in a Monetary Union*

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Abstract

This paper presents a model of a monetary union where fiscal policy remains the responsibility of national governments. Fiscal authorities may freely choose the preferences of the central bank. Once set up, nonetheless, the latter plays Nash against the former, which may decide to cooperate among themselves or not.

When national governments coordinate their policies, the standard Rogoff result about delegation holds: the optimal central bank is conservative. When they do not, however, a variety of outcomes concerning central bank preferences are possible; indeed, it may be optimal to appoint an anti-conservative central bank. It is shown that behind this variety of outcomes lies the impact of central bank preferences on fiscal externalities: a more conservative monetary authority pushes governments into an increased degree of activism, which may decrease welfare (despite a lower inflation bias) when fiscal policies generate negative spillovers.

JEL Classification: E58, F33, F42.

Sumário

Neste trabalho é apresentado um modelo de uma união monetária em que os governos dos diversos países conservam a soberania em matéria orçamental. São os referidos governos que definem as preferências do banco central da união. No entanto, uma vez instituído, este último segue uma estratégia de Nash relativamente àqueles, que, por seu turno, optam entre coordenar as respectivas políticas orçamentais ou não.

Quando os governos optam pela coordenação de políticas, a clássica conclusão de Rogoff aplica-se: o banco central óptimo é conservador. Na ausência de coordenação, pelo contrário, o banco central óptimo pode assumir uma vasta gama de preferências: pode, inclusivamente, ser anti-conservador. Subjacente a esta diversidade de preferências está o respectivo impacto sobre as externalidades decorrentes da política orçamental: um maior conservadorismo por parte da autoridade monetária leva os governos a uma utilização mais activa das políticas orçamentais, o que se poderá traduzir em perdas de bem-estar (mau-grado uma redução da inflação média) caso essas políticas sejam geradoras de externalidades negativas.

1 Introduction

Recent years have witnessed a growing interest in the study of international coordination of fiscal policies, as well as a reassessment of Rogoff's (85) delegation of monetary policy to an independent central bank (CB). Behind these developments in the academic literature lies the European scene of the 90s - as the EMU project contemplates both an independent European Central Bank, strongly committed to price stability, and a number of constraints on national fiscal policies (the Maastricht fiscal criteria for joining the single currency, and, once it comes into existence, the provisions of the Stability and Growth Pact).

The analysis of fiscal coordination (see, for instance, Jensen (96) or Krichel, Levine and Pearlman (96)) shares many of the analytical concerns of the previous international policy coordination literature[1] - which, during the 80s, had focussed attention on monetary policy. However, it also includes an original, noteworthy feature: both in verbal arguments and in formal models, it is common to find an explicit reference to an active monetary authority, alongside with governments - thus acknowledging the fact that fiscal and monetary policies are necessarily related, both by the government budget constraint and by the policy authorities' strategic interactions.

Since monetary authorities are present, their preferences over macroeconomic variables become important for the analysis. A strand of literature which may therefore provide valuable insights is the one on delegation or CB 'conservatism'. Rogoff's (85) seminal paper showed that, in a closed economy, society is made better off by delegating the conduct of monetary policy to an independent CB, conservative in the sense of assigning a higher weight to low inflation than society itself. More recent papers (Currie *et al* (96), Levine and Pearlman (97a, 97b)), however, argued that an open economy context may render delegation counterproductive: when there are several CBs to appoint, delegation acquires a strategic dimension, and countries may get trapped in a prisoner's dilemma sort of outcome.

Taking into account the previous paragraphs, this paper presents a model of a monetary union to study coordination of fiscal policies and delegation together. Again, one finds that an open economy context may change the conclusions about delegation. However, the issue here is not counterproductive delegation (since, in a monetary union, there is one single CB to appoint), but rather what the optimal CB preferences should be in the face of different kinds of fiscal behaviour. It is shown that Rogoff's conservative CB may decrease welfare when fiscal policies are not coordinated.

The paper is organized as follows. Section 2 presents the model. Section 3 derives policies under a total of four different regimes, obtained along two dimensions: cooperation *vs* non-cooperation among fiscal authorities, and choice of a CB with optimal preferences (delegation) *vs* appointment of a representative one (i.e., with the same preferences as society). Section 4 presents analytical results as regards the determination of the parameters characterizing the optimal CB preferences. Section 5 then deals with two issues: (i) it characterizes the welfare gains from delegation, in the sense of ascertaining whether they come in the form of reduced policy 'biases' or

[1]A synthesis can be found in Canzoneri and Henderson (91).

in the form of improved stabilization after shocks; and (ii) it interprets the optimal CB characteristics in the light of fiscal externalities. Section 6 concludes.

2 The Model

In this section I present a rational expectations, general equilibrium model of a monetary union with imperfect substitution between (national) goods and both fiscal and monetary policies. Real exchange rates (i.e., relative prices) adjust to clear markets. The model comprises both a self-defeating temptation to inflate (*à la* Barro-Gordon) and an explicit treatment of distortionary taxation (*à la* Alesina and Tabellini, 87). I have drawn heavily on Levine and Pearlman (97b): my model can be regarded as a simplified version of theirs[2] with a new feature added - distortionary taxes.

The world is composed of $n+1$ structurally identical economies, each producing its own composite good. The latter are imperfect substitutes in consumption. All $n+1$ countries belonging, from the outset, to a monetary union, there is one single monetary authority. Each country's government retains authority over fiscal policy. However, it is assumed that budgets must be balanced in every period: the model, therefore, does not take into account deficit or debt issues.

Variables without time subscript refer to current period t, while subscripts +1 and -1 denote periods $t+1$ and $t-1$, respectively.

The demand side

Consumers are expected utility maximizers, with an utility function given by

$$U_i = \sum_{j=0}^{n} \gamma_{ij} \log C_{ij} + \eta_i \log G_i \tag{1}$$

G_i is government spending, assumed to consist of the domestic good exclusively, and C_{ij} is country i consumption of good j (the good produced in country j), $i, j = 0, ..., n$. One has $\sum_{j=0}^{n} \gamma_{ij} = 1$, and, to simplify, I assume that the economies are perfectly integrated (i.e., the share of the national good in consumption is the same as that of any foreign good), so that $\gamma_{ij} = \gamma = 1/(n+1)$. Bilateral real exchange rates are denoted by E_{ij} and correspond to the price of good j in units of good i; thus an increase in E_{ij} means a real depreciation for country i. The budget constraint of the utility maximization problem is $C_i = \sum_{j=0}^{n} E_{ij} C_{ij}$, where good i is being used as numeraire (C_i, total consumption of country i, is determined below). Then, by maximizing (1) *s.t.* the budget constraint just mentioned, $C_{ij} = \gamma_{ij} C_i / E_{ij}$, and the demand of good i by consumers in country j is $C_{ji} = \gamma_{ji} C_j / E_{ji} = \gamma_{ji} C_j E_{ij}$. Total demand for the output of country i therefore becomes:

$$Y_i = \gamma \sum_{j=0}^{n} C_j E_{ij} + \overline{I_i} + G_i \tag{2}$$

[2]The features of Levine and Pearlman's model that I have omitted are: (i) demand shocks, (ii) partial indexation of nominal wages to actual CPI, (iii) countries outside the monetary union, (iv) employment entering the trade unions' loss function and (v) the possibility of imperfect integration.

$\overline{I}_i$ is exogenous private investment. As $E_{ij} = E_{i\mathbf{0}}/E_{j\mathbf{0}}$, one defines $E_j = E_{\mathbf{0}j}$, suppresses the 0 index and for country 0 the equation above can be written as

$$Y = \gamma \sum_{j=\mathbf{0}}^{n} C_j E_j + \overline{I} + G \tag{3}$$

The supply side

For simplicity of notation, one considers country 0. The aggregate production function is Cobb-Douglas:

$$Y = \overline{K}_{-1}^{\beta} (\overline{A}L)^{1-\beta} e^{-u^s} \tag{4}$$

$\overline{K}_{-1}$and $\overline{A}$ are the end-of-period $t-1$ capital stock and an index of human capital, respectively. They are both exogenous. u^s is an *iid* disturbance (detrimental to productivity when taking positive values). Competitive firms face a tax at rate τ on their revenues; labour is demanded according to the usual equality between the real product wage and the marginal product of labour. In logarithmic form, using the approximation $-\tau = \log(1-\tau)$:

$$w - p = f(\overline{K}_{-1}, \overline{A}) - \beta l - \tau - u^s \tag{5}$$

$f(\overline{K}_{-1}, \overline{A}) = \log(1-\beta) + (1-\beta)\log \overline{A} + \beta \log \overline{K}_{-1}$, w is the nominal wage rate, and p is the price of the domestic good (both in logs). A monopoly trade union sets w by minimizing the expected squared deviation of the real consumption wage from a target $\widehat{w}$; i.e., it minimizes $U_{TU} = (w - p^c - \widehat{w})^2$. The CPI, p^c, is given (in logs) by $p^c = p + \gamma(e_1 + e_2 + ... + e_n)$, where $e_i = \log(E_i), i = 1, ..., n$. Then:

$$w = E_{-1}(p^c) + \widehat{w} \tag{6}$$

Subtracting p from both sides, and using the CPI definition, one has:

$$w - p = -(p^c - E_{-1}(p^c)) + \gamma \sum_{j=1}^{n} e_j + \widehat{w} \tag{7}$$

From (5) and (7), one derives employment:

$$l = \frac{1}{\beta}(f(\overline{K}_{-1}, \overline{A}) - \widehat{w}) + \frac{1}{\beta}(p^c - E_{-1}(p^c) - \gamma \sum_{j=1}^{n} e_j) - \frac{1}{\beta}\tau - \frac{1}{\beta}u^s \tag{8}$$

Model closure

The model is closed by determining C_i and by making some assumption as regards the government budget constraint. The latter is assumed to be always balanced (even in the face of shocks): G_i equals tax revenues plus seignorage. For country zero, using some approximations[3]:

$$\frac{G}{Y} = \tau + \pi \tag{9}$$

[3]See Alesina and Tabellini (87), n.6, p. 622.

π, CPI inflation, equals $p^c - p^c_{-1}$. To determine C_i, balanced trade is assumed for all countries[4]:

$$\gamma \sum_{j=0;j\neq i}^{n} C_j E_{ij} = (1-\gamma)C_i \tag{10}$$

The above equation equates country i's exports (LHS) and imports (RHS).

Deviations from the steady state

All the analysis will be conducted with the variables expressed in deviations from baseline. The latter consists of the deterministic, zero-inflation, balanced trade, balanced budget, balanced growth steady state. The several assumptions made ensure that, for all practical purposes, the model is static. Lower case variables represent changes from baseline - either relative, such as $y = \log(Y/\overline{Y})$, or absolute, such as $g = G/Y - \overline{G}/\overline{Y}$, $\tau^{dev} = \tau - \tau^{st}$ or π itself. The country 0 model becomes:

$$(1-\overline{G}/\overline{Y})y = \overline{C}/\overline{Y}(\gamma(c + c_1 + e_1 + ... + c_n + e_n)) + g \tag{11}$$

$$y = \frac{1-\beta}{\beta}(\widetilde{\pi} - \gamma(e_1 + ... + e_n) - \tau^{dev}) - \varepsilon^s \tag{12}$$

$$c = c_i + e_i, \forall i \tag{13}$$

$$\tau^{dev} = g - \pi \tag{14}$$

(11) follows from (3). (12) is derived from (8) and from $y = (1-\beta)l - u^s$, which is the production function in deviation form. Notice that in the steady state $e_i = 0, \forall i$, and that l , unlike in (8), now means relative change from baseline, the latter being given by $\frac{1}{\beta}(f(\overline{K}_{-1}, \overline{A}) - \widehat{w} - \tau^{st})$; $\widetilde{\pi} = \pi - E_{-1}(\pi)$ is the inflation surprise, and $\varepsilon^s = \frac{1}{\beta}u^s$. (13) is obtained from linearizing (10) both for country 0 and for some other country i. Finally, (14) is a consequence of (9) and of $\overline{G}/\overline{Y} = \tau^{st}$. For a generic country i one adapts (11) and (12), which yields:

$$(1-\overline{G}/\overline{Y})y_i = \overline{C}/\overline{Y}[\gamma(c_i + \sum_{j=0;j\neq i}^{n}(c_j + e_j - e_i))] + g_i \tag{15}$$

$$y_i = \frac{1-\beta}{\beta}(\widetilde{\pi}_i - \gamma \sum_{j=0;j\neq i}^{n}(e_j - e_i) - \tau_i^{dev}) - \varepsilon_i^s \tag{16}$$

Apart from the i subscripts (which are not necessary for steady-state variables, as all $n+1$ economies are identical), the above equations simply explore the fact that $e_{ij} = e_j - e_i$. It is easy to check, using $e_0 \equiv 0$, that they are actually generalizations of (11) and (12).

[4]Levine and Pearlman (97a, 97b) derive balanced trade from consumers' intertemporal optimization when all economies are identical.

Solving the model

To find the rational expectations solution of the model, one first inserts (13) in (11), and (14) in (12), for country 0, and correspondingly for country i. As a result, the demand equations become:

$$y = \alpha c + \mu g \tag{17}$$

$$y_i = \alpha(c - e_i) + \mu g_i \tag{18}$$

where $\mu = 1/(1 - \overline{G}/\overline{Y})$ and $\alpha = (\overline{C}/\overline{Y})\mu$. As for the supply equations:

$$y = \frac{1-\beta}{\beta}(\widetilde{\pi} - \gamma(e_1 + ... + e_n) - g + \pi) - \varepsilon^s \tag{19}$$

$$y_i = \frac{1-\beta}{\beta}(\widetilde{\pi}_i - \gamma \sum_{j=0;j\neq i}^{n} (e_j - e_i) - g_i + \pi_i) - \varepsilon_i^s \tag{20}$$

By equating the differences $y - y_i$ given by the above demand and supply equations, one then solves for e_i - after all, the relative price that adjusts to balance relative demand and relative supply:

$$e_i = \frac{\zeta}{v}((\widetilde{\pi} - \widetilde{\pi}_i) + (\pi - \pi_i)) - \frac{\zeta + \mu}{v}(g - g_i) - \frac{1}{v}(\varepsilon^s - \varepsilon_i^s) \tag{21}$$

where $\zeta = (1-\beta)/\beta$ and $v = \alpha + \zeta$. Finally, (21) is inserted in (19), yielding:

$$y = \phi(\zeta(\widetilde{\pi} + \pi) - \varepsilon^s) + \frac{1-\phi}{n}\sum_{i=1}^{n}(\zeta(\widetilde{\pi}_i + \pi_i) - \varepsilon_i^s) + \theta g - \frac{\theta + \zeta}{n}\sum_{i=1}^{n} g_i \tag{22}$$

where $\phi = \frac{\alpha + \gamma\zeta}{\alpha + \zeta}$ and $\theta = \mu - (\mu + \zeta)\phi$. One can show that $\zeta > 0$, $0 < \alpha < 1$, $\mu > 1$, $\gamma < \phi < 1$, $\theta + \zeta > 0$ and $\theta + \frac{\theta + \zeta}{n} > 0$.

In a monetary union, however, there is a single monetary policy whose instrument is $\pi^I = \frac{1}{n+1}\sum_{i=0}^{n} \pi_i$. Perfect integration ensures that all national inflations coincide with π^I, regardless of shocks and fiscal stances[5]. Then, using the notation $x_{-i} = \sum_{j=0;j\neq i}^{n} x_j$, country i's output becomes:

$$y_i = \zeta(\widetilde{\pi}^I + \pi^I) - \phi\varepsilon_i^s - \frac{1-\phi}{n}\varepsilon_{-i}^s + \theta g_i - \frac{\theta + \zeta}{n} g_{-i} \tag{23}$$

(23) is the model's reduced form for output in a monetary union, showing how the latter depends on shocks and policy instruments exclusively. The latter are π^I,

[5]The point is that, with *imperfect* integration (i.e., bigger consumption shares taken by national goods in their respective countries), a given change in real exchange rates is only compatible with uniform CPI inflation across countries if nominal exchange rates can adjust - which is obviously impossible in a monetary union. With *perfect* integration, however, such compatibility never requires nominal appreciations or depreciations - as it is shown in Annex 1.

set by the union's central bank (CB), and $\{g_i\}_{i=0}^{n}$, each controlled by a national fiscal authority (FA). Distortionary taxes (variable τ^{dev}) come as a residual.

The sign of policy impacts on output

Monetary policy exerts a positive impact on output. The policy surprise, $\widetilde{\pi}^I$, stimulates employment and output in two ways: through the usual effect of lowering the real wage and, for given $\{g_i\}_{i=0}^{n}$, by bringing about a tax reduction. The expected policy, $\pi^I - \widetilde{\pi}^I$, is expansionary through the second channel only. By comparing (22) with (23), one concludes that, not surprisingly, monetary union leads to the internalization of monetary externalities, in the sense that the impact of monetary policy on a country's output is the same as the joint impact of *identical* policies adopted by *all* countries, when they enjoy monetary autonomy - the coefficient ζ in (23) equals $\phi\zeta + \frac{1-\phi}{n}n\zeta$, from (22).

National fiscal policies exert an ambiguous effect on home output, and have a negative impact abroad. Without loss of generality, consider fiscal policy in country zero. A rise in g induces real appreciation, as it both increases relative home demand (see (17), (18)) and decreases relative home supply (due to more taxes; see (19), (20)); the result abroad is (real) depreciation, requiring, for constant CPI inflation, a contraction in p_i (and thus in l_i and y_i as well). The impact on home output is ambiguous: on the one hand there is the positive influence via real appreciation; on the other hand, a contractionary tax rise takes place as a side effect. The net multiplier depends on the sign of the parameter θ, which is increasing in the number of countries (since ϕ decreases): with perfect integration, more foreign countries translates into a larger imported component of the CPI, which, for a given real appreciation, 'makes room' for a bigger rise in p and thus reinforces the positive impact of a fiscal expansion on y.

The fact that fiscal policy generates externalities through the real exchange rate channel - depressing (stimulating) foreign output when home spending rises (falls) - will prove central to this paper's conclusions.

3 The Four Policy Regimes

Fiscal authorities (FAs), whose preferences are taken to embody society's, and the common central bank (CB) differ only in the weights attached to the several objectives. Their loss functions are:

$$W_i^{FA} = (\pi^I)^2 + b_{FA}(y_i - \widehat{y} + u_i^s)^2 + c_{FA}g_i^2 \tag{24}$$

$$W^{CB} = \sum_{i=0}^{n}((\pi^I)^2 + b_{CB}(y_i - \widehat{y} + u_i^s)^2 + c_{CB}g_i^2) \tag{25}$$

Both are minimized *s.t.* (23). From $y_i = (1-\beta)l_i - u_i^s$, one sees that the stochastic output target $\widehat{y} - u_i^s$ follows from a fixed employment target $\widehat{l} = \widehat{y}/(1-\beta)$.

The sequencing of events is assumed to be as follows:

1. At time $t = 0$, FAs opt between a representative CB (R) or delegation (D);

2. In (a generic) period $t-1$, the union computes $E_{t-1}(\pi_t)$ and sets w accordingly;

3. In period t, the CB and the FAs observe ε_t;

4. Also in period t, the CB and the FAs simultaneously set inflation and government spending to minimize their loss functions[6]. By assumption, the CB plays Nash against the FAs. The latter, however, can choose whether to coordinate policies among themselves (C) or not (NC).

The four policy regimes (denoted by the acronyms CR, NCR, CD, NCD) result from the several possible combinations regarding events 1 and 4. The former consists of assigning a value to b_{CB}: either national governments decide that the CB should share their views on the relative weights to be attached to inflation *versus* unemployment (i.e., $b_{CB} = b_{FA}$), and one speaks of a representative CB, or the FAs choose b_{CB} in an optimal way (to be defined below), which one refers to as delegation. When it comes to setting policies (event 4), b_{CB}, however chosen, is taken as given; and thus one can derive general expressions for the policy instruments (with and without fiscal coordination) regardless of the decision made in event 1.

3.1 Cooperation *vs* Non-cooperation

When the FAs do not cooperate, the first order conditions (FOCs) are:

$$\theta b_{FA}(y_i - \widehat{y} + u_i^s) + c_{FA} g_i = 0, \ i = 0, ..., n \tag{26}$$

$$\sum_{i=0}^{n} (\pi^I + 2\zeta b_{CB}(y_i - \widehat{y} + u_i^s)) = 0 \tag{27}$$

It is possible to decompose policies into their systematic and stochastic components, which are determined independently. To obtain the former, one simplifies (23) when there are no shocks (and therefore no policy surprises). As all countries are identical, so are fiscal policies in the Nash equilibrium. Then, using upper bars for systematic components, $\overline{y}_i = \zeta(\overline{\pi}^I - \overline{g}_i)$. The FOCs become:

$$\theta b_{FA}(\zeta(\overline{\pi}^I - \overline{g}_i) - \widehat{y}) + c_{FA}\overline{g}_i = 0 \tag{28}$$

$$\overline{\pi}^I + 2\zeta b_{CB}(\zeta(\overline{\pi}^I - \overline{g}_i) - \widehat{y}) = 0 \tag{29}$$

One then solves for $\overline{\pi}^I$ and $\overline{g}_i$. As far as the stochastic components, or policy surprises, are concerned, one suppresses all systematic components from (23), (26) and (27), which yields (denoting surprises by upper tildes):

$$\theta b_{FA}(\widetilde{y}_i + \beta\varepsilon_i^s) + c_{FA}\widetilde{g}_i = 0 \tag{30}$$

$$\sum_{i=0}^{n} (\widetilde{\pi}^I + 2\zeta b_{CB}(\widetilde{y}_i + \beta\varepsilon_i^s)) = 0 \tag{31}$$

[6] The choice of policies is discretionary, in the sense that authorities are unable to commit towards the private sector (the trade union). Event 1, however, may be regarded as an institutionalized form of commitment by the FAs (Lohmann, 95), thereby facing potential credibility problems - which I ignore in the analysis.

$$\widetilde{y}_i = 2\zeta\widetilde{\pi}^I - \phi\varepsilon_i^s - \frac{1-\phi}{n}\varepsilon_{-i}^s + \theta\widetilde{g}_i - \frac{\theta+\zeta}{n}\widetilde{g}_{-i} \tag{32}$$

The ensuing stochastic policies - $\widetilde{\pi}^I$ and $\{\widetilde{g}_i\}_{i=0}^n$ - turn out to be linear functions of the shocks ε_i^s when these are decomposed into a common (or average) part $\overline{\varepsilon} = \sum_{i=0}^n \varepsilon_i^s/(n+1)$ and an idiosyncratic part $\varepsilon_i^s - \overline{\varepsilon}$. Table 1 summarizes the results while Annex 1 shows how to derive them.

When the $n+1$ fiscal authorities cooperate, they minimize *w.r.t.* $\{g_i\}_{i=0}^n$, and *s.t.* (23), the loss function given by

$$\sum_{i=0}^n W_i^{FA} = \sum_{i=0}^n (\pi_i^2 + b_{FA}(y_i - \widehat{y} + u_i^s)^2 + c_{FA}g_i^2)$$

The FOCs are:

$$b_{FA}\sum_{j=0,j\neq i}^n (y_j - \widehat{y} + u_j^s)(-\frac{\theta+\zeta}{n}) + b_{FA}(y_i - \widehat{y} + u_i^s)\theta + c_{FA}g_i = 0,\ i = 0,...,n \tag{33}$$

The FOC for the central bank - (27) - remains unchanged. Again I divide policies into systematic and stochastic components, and calculate each of them as explained for case NC. Table 1 contains the results.

Table 1 - *Optimal policies under non-cooperation (NC) and cooperation (C)*

	NC	C
$\overline{\pi}^I$	$\frac{2\zeta c_{FA}b_{CB}}{-\theta\zeta b_{FA}+c_{FA}+2\zeta^2 c_{FA}b_{CB}}\widehat{y}$	$\frac{2\zeta c_{FA}b_{CB}}{\zeta^2 b_{FA}+c_{FA}+2\zeta^2 c_{FA}b_{CB}}\widehat{y}$
$\overline{g}_i$	$\frac{\theta b_{FA}}{-\theta\zeta b_{FA}+c_{FA}+2\zeta^2 c_{FA}b_{CB}}\widehat{y}$	$-\frac{\zeta b_{FA}}{\zeta^2 b_{FA}+c_{FA}+2\zeta^2 c_{FA}b_{CB}}\widehat{y}$
$\widetilde{\pi}^I$	$w_1\overline{\varepsilon}$ $w_1 = \frac{2\zeta b_{CB}c_{FA}(1-\beta)}{-\theta\zeta b_{FA}+c_{FA}+4\zeta^2 c_{FA}b_{CB}}$	$w_1\overline{\varepsilon}$ $w_1 = \frac{2\zeta b_{CB}c_{FA}(1-\beta)}{\zeta^2 b_{FA}+c_{FA}+4\zeta^2 c_{FA}b_{CB}}$
$\widetilde{g}_i$	$(w_2+w_3)\overline{\varepsilon} + w_3(\varepsilon_i^s - \overline{\varepsilon})$ $w_2+w_3 = \frac{\theta b_{FA}(1-\beta)}{-\theta\zeta b_{FA}+c_{FA}+4\zeta^2 c_{FA}b_{CB}}$ $w_3 = -\frac{\theta b_{FA}(1-\beta)(1-\alpha)}{(\alpha+\zeta)[\theta b_{FA}(\theta+\frac{\theta+\zeta}{n})+c_{FA}]}$	$(w_2+w_3)\overline{\varepsilon} + w_3(\varepsilon_i^s - \overline{\varepsilon})$ $w_2+w_3 = -\frac{\zeta b_{FA}(1-\beta)}{\zeta^2 b_{FA}+c_{FA}+4\zeta^2 c_{FA}b_{CB}}$ $w_3 = -\frac{b_{FA}(\theta+\frac{\theta+\zeta}{n})(1-\beta)(1-\alpha)}{(\alpha+\zeta)[b_{FA}(\theta+\frac{\theta+\zeta}{n})^2+c_{FA}]}$

Some remarks should be made at this point. Firstly, while the CB only responds to the average shock $\overline{\varepsilon}$, fiscal policy remains decentralized, and thus, in general, $\widetilde{g}_i$ depends on both $\overline{\varepsilon}$ and the national idiosyncratic shock $\varepsilon_i^s - \overline{\varepsilon}$. Exceptions (or rather, limiting cases) are the situations of a common shock ($\varepsilon_i^s = \overline{\varepsilon}$) and of an anti-symmetric shock (defined by $\overline{\varepsilon} = 0$), where $\widetilde{g}_i$ simplifies to $(w_2 + w_3)\overline{\varepsilon}$ and $w_3\varepsilon_i^s$, respectively. Furthermore, the response of governments to the idiosyncratic component of shocks (given by w_3) does not depend on b_{CB}: as the CB does not respond to this disturbance component, its preferences do not influence the (Nash) equilibrium parameter w_3.

Secondly, and at least as important, under NC fiscal policy coefficients have an ambiguous sign - a consequence of the ambiguity of the sign of θ, discussed before. I hence subdivide non-cooperation into cases NC1, where $\theta < 0$, and NC2, in which $\theta > 0$ and $-\theta\zeta b_{FA} + c_{FA} > 0$[7]. In the former case, the tax effect outweighs the real appreciation effect, and therefore the FAs' systematic policies (or those in the wake of a common shock $\overline{\varepsilon} > 0$) consist of spending cuts. In the latter (NC2), on the contrary, the real appreciation effect is stronger, leading national governments into spending expansions. When all countries do the same, however, fiscal policy impacts on real exchange rates cancel each other out, and only the accompanying tax changes remain - which makes spending expansions self-defeating. Naturally, under cooperation, we observe spending/tax cuts ($\overline{g}_i < 0$ and $\widetilde{g}_i < 0$ in the event of a common positive disturbance).

Policies under the different cases are best visualized as the intersection of the policymakers' reaction functions (RFs). These result from the appropriate FOCs and are sketched in figures 1 and 2 for the situations where all national fiscal policies are equal[8]. Notice the contrast between cases NC1 and NC2 as far as $\overline{g}_i$ and $\widetilde{g}_i$ are concerned. Annex 1 gives details (including the figures' key).

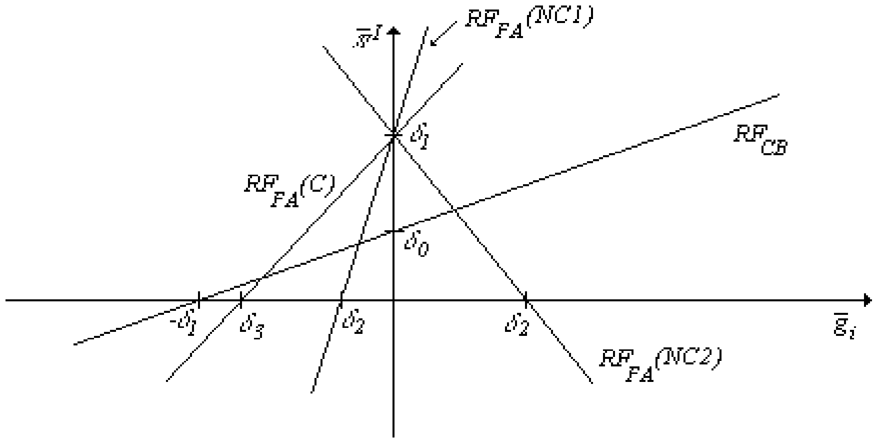

Figure 1: RFs for deterministic policy components

3.2 Delegation *vs* Representative CB

I now consider the problem facing the FAs at event 1 of the game. If governments choose to have a representative CB, one simply sets $b_{CB} = b_{FA}$ in the policies of Table

[7]Hence the region of the parameter space defined by $-\theta\zeta b_{FA} + c_{FA} < 0$ is excluded from the analysis. In this region the Nash equilibrium among the $n+1$ FAs is *unstable*: for $\overline{\pi}^I < \frac{1}{\zeta}\widehat{y}$, all the FAs are contracting ($\overline{g}_i < 0$), not because each of them thinks that such restraint will stimulate its economy (as in case NC1), but rather because all the others are contracting *and this drives y_i above $\widehat{y}$.*

[8]Two remarks should be made at this point: (i) the aim of both figures is simply to depict the relative positions of the reaction functions, rather than provide a rigorous graphical representation thereof; and (ii) any comparisons of relative slopes and intercepts should only be made within each figure – not across them.

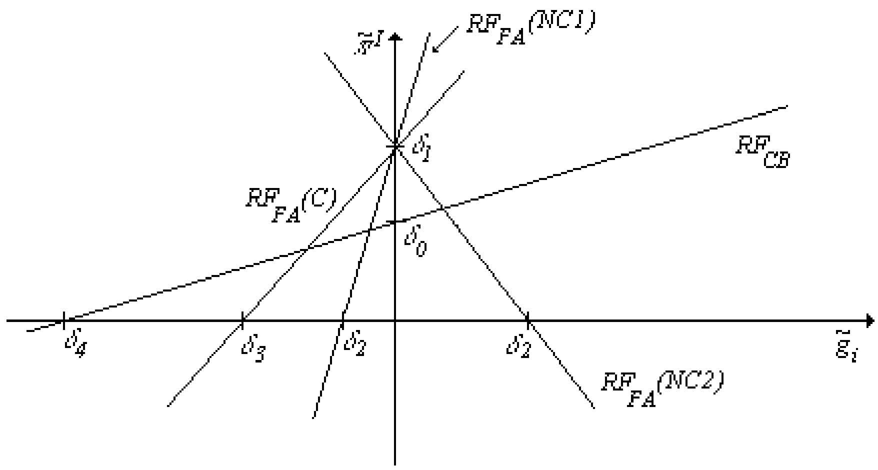

Figure 2: RFs for stochastic policy components under a common shock $\varepsilon > 0$

1[9]. If, instead, FAs decide to appoint an independent CB (a delegation regime), the optimal value of b_{CB} is found by minimizing the *expected* welfare loss of the FAs - (24) - after inserting in it the values of the policy instruments $\pi^I = \overline{\pi}^I + \widetilde{\pi}^I$ and $g_i = \overline{g}_i + \widetilde{g}_i$ that follow from either C or NC, and the subsequent expression for y_i.

In order to perform such minimization, one must specify the joint distribution of the *iid* national supply shocks: it is assumed that they are characterized by $E(\varepsilon_i^s) = 0$, $V(\varepsilon_i^s) = \sigma^2$, $i = 0, ..., n$ and $E(\varepsilon_i^s.\varepsilon_j^s) = \rho\sigma^2$, $i \neq j$ (i.e., for any pair of countries, the correlation coefficient is given by ρ). Therefore, all $n + 1$ economies are identical *ex-ante* as far as stochastic disturbances are concerned. Notice that this assumption provides a (sufficient) condition for all countries to agree on the same optimal value for b_{CB}. Notice, as well, that the polar cases of an anti-symmetric shock ($\overline{\varepsilon} = 0$) and of a common shock correspond, respectively, to the lower and upper bounds of the possible values for ρ: as $V(\overline{\varepsilon}) = \frac{1}{n+1}\sigma^2(1 + n\rho)$, it holds that $\rho \in [-\frac{1}{n}, 1]$.

When delegation leads to a value for b_{CB} such that $b_{CB} < b_{FA}$, the CB thus appointed is said to be 'conservative' - in the sense of assigning a lower weight to employment than society does. The opposite happens for $b_{CB} > b_{FA}$ - in which case the CB is 'anti-conservative'.

Figures 1 and 2 provide an illustration of how policy instruments are affected by delegation. In both, a change in b_{CB} makes RF_{CB} pivot on the intersection with the g axis, thereby crossing the relevant RF_{FA} (which does not move) at a different point. The slope of RF_{CB} increases with b_{CB}. One can hence conclude, for instance, that more 'conservatism' always translates into lower inflation and higher spending changes (in absolute value) - as a lower b_{CB} shifts activism from monetary to fiscal policy[10].

[9] Notice that the parameter c_{CB} does not play any role, as the CB takes government spending as given.

[10] The same conclusions can naturally be drawn by inspection of the expressions for $\overline{\pi}^I$, $\overline{g}_i$, w_1 and $w_2 + w_3$ - see Table 1.

4 The Optimal Choice of b_{CB}: Some Analytical Results

To solve the delegation problem - min $E(W_i^{FA})$ *w.r.t.* b_{CB} - one must resort to numerical methods, since a closed form solution for b_{CB} cannot in general be obtained. This might make any conclusions dependent on the particular parameter values one chooses to calibrate the model. However, it turns out to be possible to derive some analytical results regarding the optimal choice of b_{CB} - thus forming a basis for general conclusions. The latter are the object of Section 5. Here I present the former (i.e., the analytical results) and attempt to provide some intuition. The mathematical derivations are contained in Annex 2.

$E(W_i^{FA})$ can be rewritten in a way that reflects the subdivision of policies into deterministic and stochastic components. Using $\widetilde{l}_i = (\widetilde{y}_i + \beta\varepsilon_i^s)/(1-\beta)$, some algebra shows that:

$$E(W_i^{FA}) = (\overline{\pi}^I)^2 + b_{FA}(\overline{y}_i - \widehat{y})^2 + c_{FA}\overline{g}_i^2 + V(\widetilde{\pi}^I) + b_{FA}(1-\beta)^2 V(\widetilde{l}_i) + c_{FA}V(\widetilde{g}_i) \quad (34)$$

I now introduce some notation. Let $\overline{W}_i^{FA}$ designate the sum of the first three terms on the RHS of (34), and $\widetilde{W}_i^{FA}$ denote the sum of the remaining three terms. Let $\overline{b}_{CB}$ denote the solution to the delegation problem considering only $\overline{W}_i^{FA}$ - i.e., the optimal b_{CB} in a deterministic setting. Let $\widetilde{b}_{CB}$ stand for the optimal value when attention is restricted to $\widetilde{W}_i^{FA}$. The overall optimum is represented by b_{CB}^*. Although b_{CB}^* cannot be obtained analytically, both $\overline{b}_{CB}$ and $\widetilde{b}_{CB}$ can. Their values are given by:

	$\overline{b}_{CB}$	$\widetilde{b}_{CB}$
C	$\frac{b_{FA}}{2}$	b_{FA}
NC	$\frac{b_{FA}}{2}\cdot\frac{c_{FA}+\theta^2 b_{FA}}{c_{FA}-\theta\zeta b_{FA}}$	$b_{FA}\cdot\frac{c_{FA}+\theta^2 b_{FA}}{c_{FA}-\theta\zeta b_{FA}}$

A first observation to be made is that, either under C or NC, $\widetilde{b}_{CB} = 2\overline{b}_{CB}$: as unanticipated inflation has twice as much impact on output as systematic inflation (see equation (23)), the optimal CB for shock stabilization alone is only 'half as conservative' as the one for the deterministic part of the problem. A second remark - which may be seen as a slight qualification to the table above - is that, for $\rho = -1/n$ (i.e., when shocks are always anti-symmetric), $\widetilde{b}_{CB}$ is as good as any other value: as argued before, for such shocks the CB remains passive, which makes its preferences irrelevant. Finally, it holds that both the deterministic and the stochastic welfare losses ($\overline{W}_i^{FA}$ and $\widetilde{W}_i^{FA}$, respectively) strictly increase[11] as b_{CB} moves away from the respective optima ($\overline{b}_{CB}$ and $\widetilde{b}_{CB}$).

As far as the overall optimum is concerned, Annex 2 shows that b_{CB}^* is unique and satisfies:

$$\overline{b}_{CB} \leqslant b_{CB}^* < \widetilde{b}_{CB}$$
$$\partial b_{CB}^*/\partial\widehat{y} \leqslant 0;\ \partial b_{CB}^*/\partial\sigma^2 \geqslant 0;\ \partial b_{CB}^*/\partial\rho > 0$$

[11] Again, with the exception of $\rho = -1/n$.

For $\rho = -1/n$, $b^*_{CB} = \overline{b}_{CB}$. All the equality signs above actually refer to anti-symmetric shocks. The first two partial derivatives reflect the relative importance of deterministic and stochastic losses: for instance, as $\widehat{y}$ increases, deterministic losses become more important, 'pushing' b^*_{CB} closer to $\overline{b}_{CB}$. As ρ rises, the national shocks ε^s_i do not become more volatile in themselves; however, the average shock does, as individual disturbances tend not to compensate one another. As it is $\overline{\varepsilon}$ that matters for the choice of CB preferences, and $V(\overline{\varepsilon})$ increases, stochastic losses gain relative importance[12]: thus, $\partial b^*_{CB}/\partial \rho > 0$.

5 Central Bank Conservatism and the Gains from Delegation

In this section the preceding results are used to interpret the optimal choice of b_{CB} and its impact on welfare - i.e., I will be comparing regimes NCR *vs* NCD, and CR *vs* CD. By construction, delegation is always welfare-improving: all countries being alike, *and* there being a single CB to appoint, the choice of b^*_{CB} becomes a standard optimization problem, without any strategic aspects and hence free of the possibility of any welfare-inferior Nash equilibria[13]. However, $\overline{W}^{FA}_i$ and $\widetilde{W}^{FA}_i$ may either rise or fall, while both $b^*_{CB} < b_{FA}$ and $b^*_{CB} > b_{FA}$ are possible. This contrasts with Rogoff's (85) closed economy framework, in which delegation always takes the form of CB conservatism and implies suboptimal shock stabilization in return for a smaller inflation bias (i.e., in my notation, $b^*_{CB} < b_{FA}$, $\overline{W}^{FA}_i$ falls and $\widetilde{W}^{FA}_i$ rises).

Tables 2 and 3 report the results of five numerical simulations, and will be used to illustrate a range of different cases. All five examples take $\beta = 0.3$, $\overline{C}/\overline{Y} = 0.6$, $\overline{G}/\overline{Y} = 0.2$, $\widehat{l} = 5$ and $\sigma^2_u = 9$[14]. Without loss of generality, I set $b_{FA} = 1$ (so that, under R, $b_{CB} = 1$). Cases NC1 and NC2 are generated by setting $n = 3$ ($\Rightarrow \theta = -0.30$) and $n = 7$ ($\Rightarrow \theta = 0.04$), respectively. The difference between examples 2 and 3 (and between 4 and 5) arises from changing c_{FA} (from examples 1 to 5, c_{FA} equals successively 1, 1, 0.25, 0.25 and 0.1). $\Delta\overline{W}^{FA}_i$ and $\Delta\widetilde{W}^{FA}_i$ denote changes from R to D, and are reported for $\rho = \frac{n-1}{2n}$ (an intermediate correlation). Notice that, under D, $\overline{W}^{FA}_i$ depends indirectly on ρ, as the latter affects b^*_{CB}.

[12] One should actually say stochastic losses associated with the average shock. Losses due to the idiosyncratic shock component decrease, as $V(\varepsilon^s_i - \overline{\varepsilon}) = \sigma^2 \frac{n(1-\rho)}{n+1}$ is decreasing in ρ.

[13] These may arise when several CB exist, and event 1 - the choice of b_{CB} - thus becomes a Nash game. See Currie *et al* (96) and Levine and Pearlman (97a, 97b).

[14] This is the calibration used in Levine and Pearlman (97b). It should be stressed that the purpose of these simulations is merely to illustrate analytical results, rather than produce realistic numerical magnitudes. Note that $\sigma^2_u = V(u^s) = \beta^2\sigma^2$.

Table 2 - *Delegation: optimal b_{CB} and impact on welfare*

Ex.	Regime	$\overline{b}_{CB}$	b^*_{CB} $\rho = \frac{n-1}{2n}$	b^*_{CB} $\rho = 1$	$\widetilde{b}_{CB}$	$\Delta\overline{W}_i^{FA}$ $\rho = \frac{n-1}{2n}$	$\Delta\widetilde{W}_i^{FA}$ $\rho = \frac{n-1}{2n}$
1	C	0.50	0.68	0.76	1.00	-0.0963	0.0280
2	NC1	0.32	0.41	0.46	0.64	-0.2357	0.0137
3	NC1	0.18	0.25	0.28	0.36	-0.5286	-0.0876
4	NC2	0.80	0.97	1.08	1.59	-0.0014	0.0013
5	NC2	6.32	7.59	8.43	12.64	-0.0732	-0.0440

Cooperation (example 1) always calls for a conservative CB. As we move from CR to CD, b_{CB} falls from 1 (i.e., b_{FA}) to a value in the [0.5;1[interval. Hence $\overline{W}_i^{FA}$ falls, as delegation brings b_{CB} *closer* to $\overline{b}_{CB}$. The opposite takes place with $\widetilde{W}_i^{FA}$[15], since delegation moves b_{CB} *away* from $\widetilde{b}_{CB}$. As $E(W_i^{FA})$ must fall, $\left|\Delta\overline{W}_i^{FA}\right| > \left|\Delta\widetilde{W}_i^{FA}\right|$. Overall, the case for appointing a conservative CB is much the same as Rogoff's (85): a poorer response to disturbances is the price to be paid for a reduction in the inflation bias.

In case NC1, delegation also leads to a conservative CB - often a very conservative one[16]. Like under C, $\overline{W}_i^{FA}$ always falls. The impact of D on $\widetilde{W}_i^{FA}$, however, is ambiguous, as b^*_{CB} (coming from a value of 1 in R) 'undershoots' $\widetilde{b}_{CB}$: there may be losses (example 2) or gains (example 3).

Case NC2 is the one where generalizations are harder. One definitely has $\widetilde{b}_{CB} > 1$[17]; b^*_{CB}, however, may be either above or below unity. If $b^*_{CB} < 1$ (example 4, $\rho = \frac{n-1}{2n}$), $\widetilde{W}_i^{FA}$ must rise, as we move further away from $\widetilde{b}_{CB}$; and $\overline{W}_i^{FA}$ is certain to fall, since b_{CB} moves in the right direction ($b^*_{CB} < 1 \Rightarrow \overline{b}_{CB} < 1$), without 'undershooting'. If $b^*_{CB} > 1$, $\widetilde{W}_i^{FA}$ must decrease, since b_{CB} approaches $\widetilde{b}_{CB}$; as for $\overline{W}_i^{FA}$, there are surely increased losses if $\overline{b}_{CB} < 1$, but there may be gains when the opposite happens (despite the fact that b^*_{CB}'overshoots' $\overline{b}_{CB}$), as example 5 illustrates. Table 3 summarizes all possible outcomes.

Table 3 - *Delegation: a synthesis of outcomes*

Regime	Optimal CB	$\overline{W}_i^{FA}$	$\widetilde{W}_i^{FA}$
C	Conservative	$\searrow$	$\nearrow$
NC1	Conservative	$\searrow$	$\nearrow$ or $\searrow$
NC2	Conservative	$\searrow$	$\nearrow$
NC2	Anti-conserv.	$\nearrow$ or $\searrow$	$\searrow$

The non-cooperative cases clearly show that the optimal CB may either be conservative or not. Upon reflection, it is actually fiscal policy that is behind this variety of

[15] Except for $\rho = -\frac{1}{n}$, due to the irrelevance of b_{CB} for stochastic policies ($\Delta\widetilde{W}_i^{FA} = 0$).

[16] As $\frac{c_{FA}+\theta^2 b_{FA}}{c_{FA}-\theta\zeta b_{FA}} < 1$ (due to $\theta < 0$ and $-\theta < \zeta$), both $\overline{b}_{CB}$ and $\widetilde{b}_{CB}$ will be lower in NC1 than in C. Notice, however, that it is hazardous to make generalizations like "b^*_{CB} is always lower in NC1 than in C", because for $\rho \in]-\frac{1}{n}, 1]$ b^*_{CB} depends on the parameters of the model *in a way which is not the same under C and under NC* (see Annex 2).

[17] Since $\frac{c_{FA}+\theta^2 b_{FA}}{c_{FA}-\theta\zeta b_{FA}} > 1$ (due to $\theta > 0$ and $c_{FA} - \theta\zeta b_{FA} > 0$).

outcomes. In case NC1, there is a double motivation for the CB to be conservative: the standard reduction in systematic inflation, but also the fact that FAs are not internalizing the positive externalities of a fiscal contraction. A 'very conservative' CB, by 'pushing' governments into an increased fiscal activism (recall section 3.2), brings about (socially desirable) stronger fiscal contractions. In case NC2 the opposite takes place: a conservative CB actually worsens fiscal externalities, since FAs respond to lower inflation with stronger spending expansions, shown in section 3.1 to be self-defeating. The classic incentive to reduce the inflation bias is still there, but it may be outweighed by the need to keep fiscal expansions within acceptable limits - in which case $b^*_{CB} > b_{FA}$.

The previous paragraph assumes that all countries find themselves under the same circumstances; therefore, all national fiscal policies are identical, generating externalities which are positive in case NC1 and negative in case NC2. This fits the picture as regards deterministic policies, or stochastic policies in the wake of a common disturbance. Shock asymmetry, however, may change the sign of the externalities arising from $\widetilde{g}_i$. Consider an anti-symmetric shock, and, for simplicity, just two economies: country 0, with $\varepsilon^s > 0$, and country 1, with $\varepsilon^s_1 = -\ \varepsilon^s < 0$. In this case fiscal externalities are negative in NC1 and positive in NC2: in the latter, for instance, one has $\widetilde{g} < 0$, which contributes to stimulate $\widetilde{l}_1$(negatively affected by the shocks[18]), and $\widetilde{g}_1 > 0$, which helps to avoid 'overheating' of $\widetilde{l}$. One might be tempted to think that the CB should restrain (foster) fiscal activism in case NC1 (NC2) through a higher (lower) b^*_{CB}. The point, however, is that for anti-symmetric shocks the CB simply does not intervene. More generally, the CB does not respond to the idiosyncratic component of the shocks ($\varepsilon^s_i - \overline{\varepsilon}$), but only to the common component ($\overline{\varepsilon}$): as these are independent (orthogonal), the argument of the previous paragraph carries through for whatever ρ.

Finally, it should be stressed that it is from the real exchange rate externalities of an open economy context that the possibility of an anti-conservative CB arises, rather than from the presence of distortionary taxation alone. In a closed economy with distortionary taxes, Alesina and Tabellini (87) find that the optimal CB is always conservative.

6 Concluding Remarks

In the light of this paper's model, and in the context of Nash equilibria among policy authorities, Rogoff's trade-off between a conservative CB as far as systematic policies are concerned and a representative one when it comes to shock stabilization only fits the picture when FAs are cooperating. When they are not, delegation must also take into account what its impact on fiscal externalities will be: if conservatism worsens

[18] Although it may seem paradoxical, it holds that, for an anti-symmetric shock and two economies, the country with the positive - i.e., detrimental to productivity - shock (country zero, in our example) has positive $\widetilde{l}$, and hence aims at restraining employment, rather than further stimulating it. Naturally, the opposite takes place for the other country.

them, it may be the case that the optimal CB is anti-conservative[19].

Likewise, the gains from delegation do not always take the form of a lower inflation bias, which outweighs a poorer shock stabilization. In a model with fiscal externalities the opposite can happen, or there may even be gains both on the systematic policies and on the shock stabilization fronts.

At a more general level, this paper also shows how an open-economy context can change the conclusions about delegation. Currie *et al* (96) and Levine and Pearlman (97a) have shown that delegation may be counterproductive. In this paper what may be counterproductive is not delegation in itself, but rather its standard conservative form.

Further research should aim at studying the interaction between delegation and fiscal policies under a less stringent set of assumptions. One possibility is to allow for some heterogeneity among the $n+1$ economies: for instance, Bayoumi and Eichengreen (92) point out that prospective EMU members are not at all identical *ex-ante* as far as stochastic disturbances are concerned, which might destroy consensus about b^*_{CB} and modify this paper's findings[20]. Some other possibilities are introducing demand shocks, making the trade union target employment (instead of the real wage) and suppressing seignorage from the government budget constraint[21]. This last change seems particularly relevant, as it concerns fiscal-monetary interactions, which have proved central to this paper's conclusions. Finally, it is important to extend the analysis to a dynamic framework - so as to allow for budget deficits and public debt.

References

[1] Alesina, A. and G. Tabellini (1987), "Rules and discretion with noncoordinated monetary and fiscal policies", *Economic Inquiry*, XXV, pp. 619-630.

[2] Artis, M. and B. Winkler (1997), "The Stability Pact: safeguarding the credibility of the European Central Bank", mimeo.

[3] Bayoumi, T. and B. Eichengreen (1992), "Shocking aspects of European monetary unification", CEPR Discussion Paper No. 643.

[4] Canzoneri, M. and D. Henderson (1991), *Monetary Policy in Interdependent Economies: A Game-Theoretic Approach*, MIT Press.

[5] Currie, D., P. Levine and J. Pearlman (1996), "The choice of 'conservative' bankers in open economies: monetary regime options for Europe", *The Economic Journal*, 106, March, 345-358.

[19] Although in a different context (considering deficits and debt, as well as Stackelberg games), Artis and Winkler (97) also stress that the desirability/sustainability of a conservative CB requires a disciplined fiscal policy.

[20] Preliminary investigation along these lines shows, however, that under some conditions this paper's results still hold in a 'core' *vs* 'periphery' scenario.

[21] These last two points were kindly suggested by Paul Levine - especially because, in the seignorage case, the approximations underlying equation (9) may not be very accurate.

[6] Jensen, H. (1996), "The advantage of international fiscal cooperation under alternative monetary regimes", *European Journal of Political Economy*, 12, 485-504.

[7] Krichel, T., P. Levine and J. Pearlman (1996), "Fiscal and monetary policy in a monetary union: credible inflation targets or monetized debt?", *Weltwirtschaftliches Archiv*, 132(1), 28-54.

[8] Levine, P. and J. Pearlman (1997a), "Delegation and fiscal policy in the open economy: more bad news for Rogoff's delegation game", March, mimeo.

[9] Levine, P. and J. Pearlman (1997b), "Monetary union: the ins and outs of strategic delegation", IUE, European Forum, June.

[10] Lohmann, S. (1995), "Quis custodiet ipsos custodes? Necessary conditions for price stability in Europe", in Siebert, H. (ed.), *Monetary Policy in an Integrated World Economy*, Symposium 1995, Institut fur Weltwirtschaft an der Universitat Kiel.

[11] Rogoff, K. (1985), "The optimal degree of commitment to an intermediate monetary target", *The Quarterly Journal of Economics*, 100, November,1169-1189.

Annex 1

1. I start by showing that perfect integration ensures that a common inflation rate is compatible with whatever real exchange rate adjustments are needed to clear markets. The CPIs of the different countries are given by:

$$p^c = p + \gamma(e_1 + e_2 + ... + e_n)$$
$$p_i^c = p_i + \gamma \sum_{j=0;j\neq i}^{n}(e_j - e_i),\ i = 1, ..., n$$

Consider now a uniform change k in all $n+1$ CPIs (decided by the common central bank) and a set of market clearing real exchange rate adjustments $\{\Delta e_i\}_{i=1}^{n}$. Based on the CPI definitions one can write:

$$\Delta p = k - \gamma \sum_{j=1}^{n} \Delta e_j$$
$$\Delta p_i = k - \gamma \sum_{j=0;j\neq i}^{n} \Delta e_j + n\gamma\Delta e_i,\ i = 1, ..., n$$

Rearranging the RHS (by adding and subtracting $\gamma\Delta e_i$, and noting that $e_0 \equiv 0$):

$$\Delta p = k - \gamma \sum_{j=0}^{n} \Delta e_j$$
$$\Delta p_i = k - \gamma \sum_{j=0}^{n} \Delta e_j + \Delta e_i,\ i = 1, ..., n$$

It follows that $\Delta e_i = \Delta p_i - \Delta p$, $i = 1, ..., n$. This is exactly what must hold in a monetary union, since the n real exchange rates are defined by $e_i = p_i - p$, $i = 1, ..., n$.

2. I now turn to the derivation of stochastic policies under NC. From equations (30), (31) and (32), using the notation of Table 1:

$$\widetilde{\pi}^I = w_1 \overline{\varepsilon} \tag{A.1}$$

$$\sum_{i=0}^{n} \widetilde{g}_i = (n+1)\,\frac{\theta b_{FA}(1-\beta)}{-\theta\zeta b_{FA} + c_{FA} + 4\zeta^2 c_{FA} b_{CB}}\overline{\varepsilon} \tag{A.2}$$

To obtain $\widetilde{g}_i$, one starts by replacing in (32) ε^s_{-i} by $(n+1)\overline{\varepsilon} - \varepsilon^s_i$ and $\widetilde{g}_{-i}$ by $\sum_{j=0}^{n} \widetilde{g}_j - \widetilde{g}_i$:

$$\widetilde{y}_i = 2\zeta\widetilde{\pi}^I + (\frac{1-\phi}{n} - \phi)\varepsilon^s_i - \frac{1-\phi}{n}(n+1)\overline{\varepsilon} + (\theta + \frac{\theta+\zeta}{n})\widetilde{g}_i - \frac{\theta+\zeta}{n}\sum_{i=0}^{n}\widetilde{g}_i \tag{A.3}$$

From (A.3) and (30), using also (A.1) and (A.2), one could simply solve for $\widetilde{g}_i$. Additional insight can be gained, however, by noting first that $\widetilde{g}_i$ is a linear function of ε^s_i and $\overline{\varepsilon}$: $\widetilde{g}_i = w_2\overline{\varepsilon} + w_3\varepsilon^s_i$ or, equivalently, $\widetilde{g}_i = (w_2 + w_3)\overline{\varepsilon} + w_3(\varepsilon^s_i - \overline{\varepsilon})$. The coefficients $w_2 + w_3$ and w_3 follow from the polar cases of a common shock ($\varepsilon^s_i - \overline{\varepsilon} = 0$) and an anti-symmetric shock ($\overline{\varepsilon} = 0$): the former yields $w_2 + w_3$ (from (A.2)), and the latter w_3 (from (A.3) - with the simplifications that result from $\overline{\varepsilon} = 0$ - and (30)).

The stochastic component of employment can also be expressed as a linear function of $\overline{\varepsilon}$ and $\varepsilon^s_i - \overline{\varepsilon}$ - a result which will prove useful in Annex 2. From $y_i = (1-\beta)l_i - u^s_i$ and (30), one can write $\widetilde{l}_i = -c_{FA}\widetilde{g}_i/(\theta b_{FA}(1-\beta))$. Therefore:

$$\begin{aligned} \widetilde{l}_i &= (w_4 + w_5)\overline{\varepsilon} + w_5(\varepsilon^s_i - \overline{\varepsilon}) \\ w_4 + w_5 &= -\tfrac{c_{FA}}{-\theta\zeta b_{FA} + c_{FA} + 4\zeta^2 c_{FA} b_{CB}} \\ w_5 &= \tfrac{c_{FA}(1-\alpha)}{(\alpha+\zeta)[\theta b_{FA}(\theta + \frac{\theta+\zeta}{n}) + c_{FA}]} \end{aligned}$$

Under cooperation, the stochastic components of policies and employment are derived along similar lines. In particular, it holds that:

$$\begin{aligned} \widetilde{l}_i &= (w_4 + w_5)\overline{\varepsilon} + w_5(\varepsilon^s_i - \overline{\varepsilon}) \\ w_4 + w_5 &= -\tfrac{c_{FA}}{\zeta^2 b_{FA} + c_{FA} + 4\zeta^2 c_{FA} b_{CB}} \\ w_5 &= \tfrac{c_{FA}(1-\alpha)}{(\alpha+\zeta)[b_{FA}(\theta + \frac{\theta+\zeta}{n})^2 + c_{FA}]} \end{aligned}$$

3. Finally, I present the details underlying figures 1 and 2. Each reaction function (RF) follows from simplifying the relevant FOC and solving it for the player's policy instrument. For instance, considering systematic policies, the FOC for the CB - (29) - yields as reaction function:

$$\overline{\pi}^I = \frac{2\zeta b_{CB}}{1 + 2\zeta^2 b_{CB}}\widehat{y} + \frac{2\zeta^2 b_{CB}}{1 + 2\zeta^2 b_{CB}}\overline{g}_i$$

Below one finds the equations for the several RFs[22]. Representations like figures 1 and 2 rely on the equalization of government spending across countries: hence, for stochastic policies, only the common shock (ε) case is considered. Notice that, because the FOCs already incorporate that equalization, the ensuing RF$_{FA}$ is not the 'true' RF for an individual FA, but rather a representation of the Nash equilibrium among the $n+1$ FAs for each level of inflation.

	Deterministic policies	Common shock ε
RF_{CB}	$\overline{\pi}^I = \frac{2\zeta b_{CB}}{1+2\zeta^2 b_{CB}}\widehat{y} + \frac{2\zeta^2 b_{CB}}{1+2\zeta^2 b_{CB}}\overline{g}_i$	$\widetilde{\pi}^I = \frac{2\zeta b_{CB}(1-\beta)}{1+4\zeta^2 b_{CB}}\varepsilon + \frac{2\zeta^2 b_{CB}}{1+4\zeta^2 b_{CB}}\widetilde{g}_i$
$RF_{FA}(NC)$	$\overline{\pi}^I = \frac{1}{\zeta}\widehat{y} - \frac{-\theta b_{FA}\zeta + c_{FA}}{\theta b_{FA}\zeta}\overline{g}_i$	$\widetilde{\pi}^I = \frac{\beta}{2}\varepsilon - \frac{-\theta b_{FA}\zeta + c_{FA}}{2\theta b_{FA}\zeta}\widetilde{g}_i$
$RF_{FA}(C)$	$\overline{\pi}^I = \frac{1}{\zeta}\widehat{y} + \frac{\zeta^2 b_{FA} + c_{FA}}{\zeta^2 b_{FA}}\overline{g}_i$	$\widetilde{\pi}^I = \frac{\beta}{2}\varepsilon + \frac{\zeta^2 b_{FA} + c_{FA}}{2\zeta^2 b_{FA}}\widetilde{g}_i$

As for the intersections with the axes:

	δ_0	δ_1	δ_2	δ_3	δ_4
Fig. 1	$\frac{2\zeta b_{CB}}{1+2\zeta^2 b_{CB}}\widehat{y}$	$\frac{1}{\zeta}\widehat{y}$	$\frac{\theta b_{FA}}{-\theta b_{FA}\zeta + c_{FA}}\widehat{y}$	$-\frac{\zeta b_{FA}}{\zeta^2 b_{FA} + c_{FA}}\widehat{y}$	-
Fig. 2	$\frac{2\zeta(1-\beta) b_{CB}}{1+4\zeta^2 b_{CB}}\varepsilon$	$\frac{\beta}{2}\varepsilon$	$\frac{\theta(1-\beta) b_{FA}}{-\theta b_{FA}\zeta + c_{FA}}\varepsilon$	$-\frac{\zeta(1-\beta) b_{FA}}{\zeta^2 b_{FA} + c_{FA}}\varepsilon$	$-\beta\varepsilon$

The relative slopes and intercepts of the several RFs can now be easily checked.

Annex 2

Let us consider the determination of $\overline{b}_{CB}$ first. The problem - both under NC and under C - is:

$$\min_{b_{CB}} \overline{W}_i^{FA} = (\overline{\pi}^I)^2 + b_{FA}(\overline{y}_i - \widehat{y})^2 + c_{FA}\overline{g}_i^2$$

Using $\overline{y}_i = \zeta(\overline{\pi}^I - \overline{g}_i)$ and the expressions for $\overline{\pi}^I$ and $\overline{g}_i$, one can write:

$$\min_{b_{CB}} \overline{W}_i^{FA} = (a_1^2 + b_{FA}a_2^2 + c_{FA}a_3^2)\widehat{y}$$

The parameters a_1, a_2 and a_3 are given below:

	NC	C
a_1	$\frac{2\zeta c_{FA} b_{CB}}{-\theta\zeta b_{FA} + c_{FA} + 2\zeta^2 c_{FA} b_{CB}}$	$\frac{2\zeta c_{FA} b_{CB}}{\zeta^2 b_{FA} + c_{FA} + 2\zeta^2 c_{FA} b_{CB}}$
a_2	$-\frac{c_{FA}}{-\theta\zeta b_{FA} + c_{FA} + 2\zeta^2 c_{FA} b_{CB}}$	$-\frac{c_{FA}}{\zeta^2 b_{FA} + c_{FA} + 2\zeta^2 c_{FA} b_{CB}}$
a_3	$\frac{\theta b_{FA}}{-\theta\zeta b_{FA} + c_{FA} + 2\zeta^2 c_{FA} b_{CB}}$	$-\frac{\zeta b_{FA}}{\zeta^2 b_{FA} + c_{FA} + 2\zeta^2 c_{FA} b_{CB}}$

[22] For simplicity, they have all been solved for inflation.

Differentiating the objective function yields:

	NC	C
$\frac{\partial \overline{W}_i^{FA}}{\partial b_{CB}}$	$\frac{8\hat{y}^2\zeta^2 c_{FA}^2(c_{FA}-\theta\zeta b_{FA})(b_{CB}-\overline{b}_{CB})}{(-\theta\zeta b_{FA}+c_{FA}+2\zeta^2 c_{FA}b_{CB})^3}$	$\frac{8\hat{y}^2\zeta^2 c_{FA}^2(c_{FA}+\zeta^2 b_{FA})(b_{CB}-\overline{b}_{CB})}{(\zeta^2 b_{FA}+c_{FA}+2\zeta^2 c_{FA}b_{CB})^3}$

In the table above, $\overline{b}_{CB}$ is defined as in the main text[23]. It is thus straightforward that $b_{CB} = \overline{b}_{CB}$ is indeed the minimizer. Besides, one can also check that $\overline{W}_i^{FA}$ is strictly decreasing in b_{CB} for $b_{CB} < \overline{b}_{CB}$, and increasing for $b_{CB} > \overline{b}_{CB}$.

To derive $\widetilde{b}_{CB}$ one proceeds in a similar fashion. Both under NC and C, the problem is:

$$\min_{b_{CB}} \widetilde{W}_i^{FA} = V(\widetilde{\pi}^I) + b_{FA}(1-\beta)^2 V(\widetilde{l}_i) + c_{FA}V(\widetilde{g}_i)$$

To compute the above variances, one writes $\widetilde{\pi}^I$, $\widetilde{l}_i$ and $\widetilde{g}_i$ as linear functions of the shocks (see Table 1 and Annex 1), noting that $cov(\overline{\varepsilon}, \varepsilon_i^s - \overline{\varepsilon}) = 0$. As w_3 and w_5 do not depend on b_{CB}, the objective function simplifies to:

$$\min_{b_{CB}} [w_1^2 + b_{FA}(1-\beta)^2(w_4+w_5)^2 + c_{FA}(w_2+w_3)^2]V(\overline{\varepsilon})$$

Differentiating the objective function yields:

	NC	C
$\frac{\partial \widetilde{W}_i^{FA}}{\partial b_{CB}}$	$\frac{8(1-\beta)^2 V(\overline{\varepsilon})\zeta^2 c_{FA}^2(c_{FA}-\theta\zeta b_{FA})(b_{CB}-\widetilde{b}_{CB})}{(-\theta\zeta b_{FA}+c_{FA}+4\zeta^2 c_{FA}b_{CB})^3}$	$\frac{8(1-\beta)^2 V(\overline{\varepsilon})\zeta^2 c_{FA}^2(c_{FA}+\zeta^2 b_{FA})(b_{CB}-\widetilde{b}_{CB})}{(\zeta^2 b_{FA}+c_{FA}+4\zeta^2 c_{FA}b_{CB})^3}$

One hence concludes that $b_{CB} = \widetilde{b}_{CB}$ (defined, for NC and for C, as in the main text) is the solution. Further, $\widetilde{W}_i^{FA}$ is strictly decreasing in b_{CB} for $b_{CB} < \widetilde{b}_{CB}$, and increasing for $b_{CB} > \widetilde{b}_{CB}$. An exception occurs for $\rho = -1/n$, in which case $V(\overline{\varepsilon}) = 0$, and hence $\widetilde{W}_i^{FA}$ does not depend on b_{CB}.

I will now prove the assertions made about b_{CB}^*. The problem is:

$$\min_{b_{CB}} E(W_i^{FA}) = \overline{W}_i^{FA} + \widetilde{W}_i^{FA}$$

The FOC - both under NC and C - uses the derivatives of $\overline{W}_i^{FA}$ and $\widetilde{W}_i^{FA}$ presented above; after some manipulations, one obtains:

$$\frac{b_{CB} - \overline{b}_{CB}}{\widetilde{b}_{CB} - b_{CB}} A^3 = (1-\beta)^2 V(\overline{\varepsilon})/\hat{y}^2$$

	NC	C
A	$\frac{-\theta\zeta b_{FA}+c_{FA}+4\zeta^2 c_{FA}b_{CB}}{-\theta\zeta b_{FA}+c_{FA}+2\zeta^2 c_{FA}b_{CB}}$	$\frac{\zeta^2 b_{FA}+c_{FA}+4\zeta^2 c_{FA}b_{CB}}{\zeta^2 b_{FA}+c_{FA}+2\zeta^2 c_{FA}b_{CB}}$

[23] Which means, of course, that it is *different* for the cooperative and non-cooperative cases.

The FOC is a 4th-degree expression in b_{CB}, which makes it impossible to obtain a closed form solution. However, since $A > 0$, $(1-\beta)^2 V(\overline{\varepsilon})/\widehat{y}^2 \geqslant 0$ and $\widetilde{b}_{CB} > \overline{b}_{CB}$, one must have $\overline{b}_{CB} \leqslant b^*_{CB} < \widetilde{b}_{CB}$ (the equality case corresponding to $\rho = -1/n$). Furthermore, differentiating the LHS of the FOC *w.r.t.* b_{CB}, one obtains positive expressions:

NC	$\frac{\widetilde{b}_{CB}-\overline{b}_{CB}}{(\widetilde{b}_{CB}-b_{CB})^2}A^3 + 3\frac{b_{CB}-\overline{b}_{CB}}{\widetilde{b}_{CB}-b_{CB}}A^2\frac{6\zeta^2 c_{FA}(-\theta\zeta b_{FA}+c_{FA})+16\zeta^4 c_{FA}^2 b_{CB}}{(-\theta\zeta b_{FA}+c_{FA}+2\zeta^2 c_{FA} b_{CB})^2}$
C	$\frac{\widetilde{b}_{CB}-\overline{b}_{CB}}{(\widetilde{b}_{CB}-b_{CB})^2}A^3 + 3\frac{b_{CB}-\overline{b}_{CB}}{\widetilde{b}_{CB}-b_{CB}}A^2\frac{6\zeta^2 c_{FA}(\zeta^2 b_{FA}+c_{FA})+16\zeta^4 c_{FA}^2 b_{CB}}{(\zeta^2 b_{FA}+c_{FA}+2\zeta^2 c_{FA} b_{CB})^2}$

As the LHS of the FOC is strictly increasing in b_{CB}[24], (i) b^*_{CB} is unique and (ii) $\partial b^*_{CB}/\partial\widehat{y} \leqslant 0$, $\partial b^*_{CB}/\partial\sigma^2 \geqslant 0$, $\partial b^*_{CB}/\partial\rho > 0$ (due to the impact on the RHS of the FOC of changes in $\widehat{y}$, σ^2 or ρ; again, the equality cases correspond to $\rho = -1/n$).

[24]For $b_{CB} \in [\overline{b}_{CB}, \widetilde{b}_{CB}[$. Further, notice that this paragraph's argument also rests on the fact that RHS does not depend on b_{CB}.