Can an Enlargement of the European Monetary Union Lead to a Fall in Public Investment?

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Abstract

This paper deals with monetary and fiscal policy strategic interactions within a multi-country framework representing a monetary union and investigates the politico-economic determinants of productivity-enhancing public spending. The paper also addresses the issue of the optimally designed common central bank in a game with discretionary monetary leadership. The establishment or the enlargement of a monetary union can theoretically foster as well as discourage public investment, depending on the relative preferences of governments between their various economic objectives. However, the case in which monetary unification leads to a fall in public investment seems more likely in Europe. This does not yet necessarily mean that public investment turns out to be insufficient from a social point of view. The welfare implications of the change in public investment depend both on the central bank's output-inflation trade-off and on the time preference rate of national governments.

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1. Introduction

Since the seminal articles of Aschauer (1989a, b), who attempted to estimate the marginal productivity of public capital and found a significant positive impact of public investment on productivity and aggregate output for the US economy, many empirical analyses, following alternative approaches, have been carried out with the aim of measuring the contribution of public investment expenditure towards economic growth for different OECD countries or periods. The issue of the return of public capital has generated a vivid debate and has become increasingly controversial because the various studies that have been conducted so far did not succeed in offering clear-cut conclusions as regards the precise magnitude of the impact of public investment on macroeconomic performance. Nevertheless, although the results of empirical research appear to be more or less fragile, depending on the methodology considered (European Commission, 2003; Turrini, 2004), there is all the same a consensus that public investment spending in infrastructure or human capital is likely to sustain economic growth, by enhancing productivity performance in the long run, and is as important as private investment.[1] In particular, public investment can play a leverage role in rendering private investment more productive and in stimulating private investment in productive assets (Lloyd, 1999).

The beneficial effect of public capital expenditure on economic activity has notably been put forward for explaining the impressive performance of the US during the nineties. Despite substantial reductions in defense expenditure, government investment spending has risen by some 2% per year on average during the second half of that period, which sharply contrasts with the situation in the European Union (EU), where public investment expenditure continued to fall throughout most of that decade.[2] At the end of the nineties, the level of public investment – as a share of GDP – in the US was almost twice as high as that of the EU-11 (Lloyd, 1999). Among the various factors liable to explain this downward trend in public investment levels in Europe has been the fiscal consolidation pressure from the Maastricht criteria, although the question remains open to debate (Heinemann, 2002; European Commission, 2003).[3] Now that monetary unification is achieved, the optimistic point of view, given the existing framework for fiscal stability, is that the prospect of lower future budget deficits and debts should induce governments to increase spending devoted to public investment programs. The share of public investment in GDP indeed rose on average in the EU area (by more than 2% per year) between 1999 and 2002.

Exploring whether the establishment of the European Monetary Union (EMU) and its enlargement to the East afterwards could really result in higher public investment levels appears to be relevant and motivates the present paper. Here, the question is investigated in parallel with that of the socially optimal monetary institution (i.e. the optimal degree of monetary conservatism).

Generally speaking, a higher degree of fiscal federalism is expected to be associated with higher public investment levels. I tackle this issue from a strategic standpoint in order to highlight some politico-economic factors that are instrumental in determining the share of public investment in total public expenditure. I use for that a n-country model of discretionary fiscal and monetary policymaking with commitment problems in the tradition of Barro and Gordon

[1] Some other theoretical reasons, such as the supply of public goods or the presence of various market failures, also provide a rationale for public investment.

[2] Between 1994 and 1998, the ratio of public investment to GDP registered the largest drop in the EU area, with a fall by almost 4% per year.

[3] According to the econometric results of Heinemann (2002), the fiscal constraints imposed by the Maastricht Treaty did not add to the decline in public capital spending in a significant way.

(1983).[4] This model formally describes the EMU through the strategic interaction between one central bank, which sets the common monetary policy for the entire union, and n national governments, which select their fiscal policy in a non-cooperative fashion and impose externalities on one another by affecting the union's inflation rate. The paper examines the Stackelberg solution with monetary leadership, which depicts the better commitment technology of the monetary player (Debelle, 1996). Following the recent work by Ismihan and Ozkan (2003a, b, c), I distinguish current non-productive spending, which does not affect output, from productivity-enhancing public spending, which boosts activity in the long run. The model is dynamic with two periods for representing the consequences of public investment for future macroeconomic performance.

The main point in this paper is that governments use public investment policy in a strategic way with the aim of affecting future inflation expectations and economic outcomes. Whenever the central banker moves first, in the absence of any adjustment of his output-inflation trade-off, the equilibrium inflation rate is either too high or too low when compared with the socially optimal rate. Each fiscal authority is then induced to reappraise its public investment strategy in order to alter the trend in monetary policy for getting closer to the optimum. Nevertheless, in a monetary union, the optimal inflation rate is like a public good from the perspective of an individual member state, so that the incentive for a country to contribute to this public good, by reviewing the level of public capital expenditure, directly depends on the *ex ante* perceived effects of its own measures on the future common monetary policy. In this setting, it is shown that, as long as the monetary policymaker's trade-off has not been adjusted, the establishment – or, equivalently, the enlargement – of a monetary union can theoretically promote as well as discourage public investment, depending on the relative preferences of governments between their various economic objectives. However, the case according to which the monetary union entails a drop in public investment, and hence harms the future growth potential of participating countries, appears more likely in the European context. Thus, a decline in public investment can theoretically be explained on purely strategic grounds, irrespective of the tight fiscal rules imposed by the Maastricht criteria and by the Stability and Growth Pact (SGP). On the other hand, if the central bank's output-inflation trade-off is correctly adjusted, the public investment level is disconnected from any consideration about the size of the monetary union. In such a case, the common central banker might be made weight-liberal to increase the inflation bias deliberately.

Another question of interest concerns the welfare implications of the possible change in the share of productive expenditure following monetary unification. In particular, could public investment turn out to be systematically insufficient from a social point of view? The answer to this question mainly depends on the price stability weight in the central bank's loss function, and on the degree at which governments discount future events. In fact, the possible curtailment in productive spending does not necessarily imply that public investment is always too low when compared with the optimum. Somewhat paradoxically, if the central banker is the dominant player in the game, there can be overinvestment even in the presence of myopic governments whose rate of time preference exceeds that of societies.

The size of the monetary union also appears to have important consequences for the optimal level of public investment. Depending whether public investment is excessive or, on the contrary, too small from a social point of view, and on the relative preferences of national governments, any enlargement of the union may exert favorable or adverse effects on welfare, as it directly impacts on the equilibrium level of public capital expenditure, and hence on the distribution of distortions between the two periods of the game. In this setting, it is shown that the optimal size of the EMU can formally be either finite or infinite.

[4] This model is notably used by Beetsma and Bovenberg (1998, 1999, 2000, 2003).

The remainder of the paper is organized as follows. Section 2 sets out the model. The equilibrium values of control and state variables in the two periods of the game are calculated in Section 3. The model is solved for the common central banker's optimal degree of inflation aversion in Section 4. I then explore, on the basis of intratemporal welfare losses, how monetary unification can affect the level of productivity-improving public expenditure, depending on the relative preferences of governments. Section 5 considers intertemporal losses and the political distortions associated with myopia to determine the conditions under which public investment is either insufficient or excessive from a social standpoint. Finally, Section 6 concludes. The appendix provides all the technical derivations.

2. The n-country model

Following Beetsma and Bovenberg (1998, 1999, 2000, 2003), the monetary union is formally represented by a n-country version of the standard Alesina and Tabellini (1987) model of discretionary policymaking in a closed economy. The model is extended to two periods to take into account the implications of public investments for future performance.

The economic and monetary union consists of n participating countries. As will be clear below, the value of n plays an important role here. The case n = 1 coincides with insular monetary policymaking, while an increase in n can be seen alternatively as the establishment of a monetary union or as the enlargement of an already existing monetary union. It is assumed for simplicity that all countries are structurally identical and produce perfectly substitutable commodities, so that the inflation rate (directly fixed by the common central bank) is uniform across the union.

As in Ismihan and Ozkan (2003a, b, c), the main point is that output depends on the productivity level, too. A representative competitive firm of country i (i = 1,..., n) faces the production function $Y_{i,\mathrm{t}} = A_{i,\mathrm{t}}(L_{i,\mathrm{t}})^{\alpha}$, where Y_t, A_t and L_t represent output, productivity and labor in period t, respectively, and $0 < \alpha < 1$. The firm is a price taker on every market and has to maximize profits, $P_\mathrm{t}Y_{i,\mathrm{t}}(1 - \tau_{i,\mathrm{t}}) - W_\mathrm{t}L_{i,\mathrm{t}}$, where P_t and W_t respectively denote the price level and the nominal wage rate in period t, which are the same across the union, and where $\tau_{i,\mathrm{t}}$ is the tax rate on the total revenue of country i's firm in period t. Any increase in the tax rate leads to a fall in profitability and thus results in lower output. Nominal wage contracts are signed before policies are chosen. The nominal wage rate in period t is set equal to the rationally expected price level for this period; hence, $w_\mathrm{t} = (p_\mathrm{t})^\mathrm{e}$, where lower case letters represent logs and where the superscript "e" denotes a rational expectation. It is straightforward to see that output in country i is then given by $y_{i,\mathrm{t}} = (\alpha/(1 - \alpha))[p_\mathrm{t} - (p_\mathrm{t})^\mathrm{e} - \tau_{i,\mathrm{t}} + a_{i,\mathrm{t}}/\alpha + \log(\alpha)]$, where $\log(1 - \tau_{i,\mathrm{t}})$ has been approximated by $(-\tau_{i,\mathrm{t}})$.

I follow the hypothesis of Ismihan and Ozkan (2003a, b, c) that productivity for a given period directly depends on the public investment level selected by fiscal authorities in the former period. So, in country i, $a_{i,\mathrm{t}} = \beta_0 g^{\mathrm{I}}_{i,\mathrm{t}-1}$, where g^{I} denotes productivity-increasing public expenditure and $\beta_0 > 0$. Substituting $a_{i,\mathrm{t}}$ into the output equation above, setting $\beta = \beta_0/\alpha$ and $\alpha = ½$ for algebraic simplicity and normalizing output by subtracting the constant term $(\alpha/(1 - \alpha))\log(\alpha)$ yields the following output supply function:

$$x_{i,\mathrm{t}} = \pi_\mathrm{t} - \pi^\mathrm{e}_\mathrm{t} - \tau_{i,\mathrm{t}} + \beta g^{\mathrm{I}}_{i,\mathrm{t}-1}, \tag{1}$$

where x is normalized output and where π stands for the inflation rate.

I take up again the distinction made in Ismihan and Ozkan (2003a, b, c) between public consumption spending (g^{C}), which is assumed here to be non-productive and to have no effect on economic activity but yields instant utility to fiscal authorities (on political and electoral grounds, for instance), and public investment spending (g^{I}), which has a positive impact on overall productivity and makes it possible to increase output in the next period, as seen above. Current non-productive spending is made up of public sector wages, transfers and social security spending, among others. Public investment is notably composed of spending in infrastructure, including transport and telecommunication networks, in human capital (i.e. education and training) and in research and development.

The government budget constraint creates a link both between monetary and fiscal policies within each period and between optimization decisions across different periods:

$$g_{i,\mathrm{t}}^{\mathrm{C}} + g_{i,\mathrm{t}}^{\mathrm{I}} = \pi_{\mathrm{t}} + \tau_{i,\mathrm{t}}. \tag{2}$$

I exclude borrowing as a source of finance for abstracting from the issue of strategic public debt accumulation, and solely focus on the possibility of strategic behavior as regards public investment decisions. The two categories of public expenditure can then be financed only by distortionary taxation and seigniorage. All countries share equally in the seigniorage revenues of the common central bank and thus get the same share π_{t}.[5, 6]

Each society features a standard welfare function defined over inflation, output (i.e. employment) and public consumption spending for two periods:

$$V_i^{\mathrm{S}} = L_{i,1}^{\mathrm{S}} + \rho_{\mathrm{S}} L_{i,2}^{\mathrm{S}} = \tfrac{1}{2}\sum_{\mathrm{t}=1}^{2} \rho_{\mathrm{S}}^{\mathrm{t-1}} \left[s_\pi \pi_{\mathrm{t}}^2 + \left(x_{i,\mathrm{t}} - x_{\mathrm{t}}^* \right)^2 + s_g \left(g_{i,\mathrm{t}}^{\mathrm{C}} - g_{\mathrm{t}}^* \right)^2 \right], \tag{3}$$

where the superscript "S" is used for society.

It is supposed for simplicity that all countries have analogous preferences. Welfare losses increase in the deviations of inflation, output and public consumption spending from their targets. The targeted inflation rate is taken to be zero and thus corresponds to price stability. x_{t}^* and g_{t}^* are the desired levels of output and public consumption spending, respectively, for the t-th period (t = 1, 2). x_{t}^* represents the first-best level of output in the absence of any distortion,[7] while g_{t}^* denotes the optimal public consumption spending level as a share of non-distortionary output. Public capital expenditure is not itself an economic policy objective, in that there is no targeted value for this variable, but it enters in the determination of welfare through its impact on activity and employment. s_π and s_g are positive and parameterize the preferences of society *i* for the inflation and current spending objectives, respectively, relative

[5] Note that the ratio of real base money holdings to non-distortionary output (i.e. the inverse of money velocity) is here assumed to equal unity for simplifying the algebra a little and for highlighting the different cases monetary leadership leads to more clearly. In fact, in modern economies with efficient payment systems, and hence low holdings of base money, seigniorage revenues tend to be small. The important implications of small money holdings as regards the optimal monetary arrangement and the impact of monetary unification on public capital expenditure will be examined in Section 4.

[6] For convenience, I shall suppose throughout the rest of the paper that there is no public investment spending in t = 0 nor in t = 2 (so $x_{i,1} = \pi_1 - \pi_1^{\mathrm{e}} - \tau_{i,1}$ and $g_{i,2}^{\mathrm{C}} = \pi_2 + \tau_{i,2}$).

[7] The first-best output level can be achieved only by removing tax and non-tax distortions. Tax distortions directly result from the absence of lump-sum taxes, while non-tax distortions are mainly due to commodity or labor market imperfections.

to its dislike of output deviations (which is normalized to unity). ρ_S denotes the subjective discount factor of society ($0 < \rho_S < 1$).

Governments (i.e. national fiscal authorities) have a comparable objective function with the same targets and the same weighting coefficients. The sole difference with the preceding function is about the effective rate at which they discount future events. Government *i* faces the following loss:

$$V_i^{\mathrm{G}} = L_{i,1}^{\mathrm{G}} + \rho_{\mathrm{G}} L_{i,2}^{\mathrm{G}} = \tfrac{1}{2}\sum_{\mathrm{t}=1}^{2} \rho_{\mathrm{G}}^{\mathrm{t-1}} \left[s_\pi \pi_{\mathrm{t}}^2 + \left(x_{i,\mathrm{t}} - x_{\mathrm{t}}^* \right)^2 + s_g \left(g_{i,\mathrm{t}}^{\mathrm{C}} - g_{\mathrm{t}}^* \right)^2 \right], \tag{4}$$

where the superscript "G" stands for government.

ρ_G is the subjective discount factor of fiscal authorities ($0 < \rho_G < 1$). It is well-known that electoral uncertainty or political instability may make governments short-sighted and give them a higher rate of time preference than that of societies (i.e. $\rho_G < \rho_S$). In the present model, the possibility for the incumbent of being out of office at the end of the first period impacts on the composition of overall public expenditure between consumption spending and investment spending, as will be seen below.

The European Central Bank (ECB) cares about deviations of inflation and output from their ideal levels:

$$V^{\mathrm{ECB}} = L_1^{\mathrm{ECB}} + \rho_{\mathrm{S}} L_2^{\mathrm{ECB}} = \tfrac{1}{2}\sum_{\mathrm{t}=1}^{2} \rho_{\mathrm{S}}^{\mathrm{t-1}} \left[b_\pi \pi_{\mathrm{t}}^2 + \frac{1}{\mathrm{n}} \sum_{j=1}^{\mathrm{n}} \left(x_{j,\mathrm{t}} - x_{\mathrm{t}}^* \right)^2 \right]. \tag{5}$$

The ECB equally weights the interests of all countries as regards output and has the same discount factor as societies. Notice that the common central banker does not care about the consumption spending level directly, insofar as the government spending objective is not an entry in his loss function. Nevertheless, he takes into account the budget constraint of governments when internalizing their reaction function in the leader-follower policy regime. b_π is positive and measures the relative importance the ECB attaches to price stability compared to output. The monetary decision-making authority is "conservative" in the well-known Rogoff (1985) sense when it has a greater concern for inflation than societies (i.e. $b_\pi > s_\pi$), and "anti-conservative", or weight-liberal, in the opposite case, when $b_\pi < s_\pi$.

3. Stackelberg equilibrium with monetary leadership

Rather than considering the usual non-cooperative Nash game in which all players move simultaneously, I choose to model the strategic interaction among authorities by means of a Stackelberg game with discretionary monetary leadership. In fact, there is no particular reason to consider the Nash equilibrium rather than other solution concepts. The question is still open to debate (Dixit and Lambertini, 2000, 2001, 2003; Cavallari and Di Gioacchino, 2003).

On the one hand, fiscal leadership can be justified on account of the greater flexibility of the monetary instrument: as monetary policy decisions can be implemented more quickly than fiscal policy decisions,[8] every government in the monetary union should have a first-mover advantage (Beetsma and Bovenberg, 1998; Andersen, 2002; De Bonis and Della Posta, 2004).

[8] Fiscal policy is typically set on an annual basis and even usually adopted for several years running.

On the other hand, the Stackelberg solution concept can also be interpreted as reflecting the strength of the commitment technology available to players; the first-mover situation is then the result of the leader's pre-commitment capacity. Accordingly, the timing assumption according to which the central bank chooses its policy before the fiscal authority implies that the former has a commitment power *vis-à-vis* the latter. Hence, monetary leadership is an additional way to capture the notion of central bank independence (Petit, 1989; Hughes Hallett and Petit, 1990; Debelle, 1996; Cooper and Kempf, 2000; Dixit and Lambertini, 2000, 2001, 2003). Moreover, in the specific context of the EMU, an alternative interpretation for monetary leadership rests on the fact that the ECB deals with numerous national policymakers, which is likely to strengthen the strategic position of the common central bank against each government (Van Aarle, 1996). From a strategic standpoint, the monetary policymaking authority could take advantage of fiscal decentralization and impose its choices more easily. The fact that many governments face a centralized monetary authority actually means that each fiscal decision-maker taken separately has little incentive to internalize the monetary reaction to his own policy.[9]

The timing of events in this two-period game is as follows:

1. In t = 1:
   - The private sector forms expectations π_1^e.
   - Government i (i = 1,…, n) determines the optimal level of public investment $g_{i,1}^{I}$.
   - Policies are set sequentially in a two-move subgame in which inflation expectations are taken as given: monetary policy (π_1) is announced and implemented before fiscal policies $(\tau_{i,1})$, so the ECB takes into account the first-period reaction function of each government, which is a follower.
2. In t = 2:
   - The private sector forms expectations π_2^e.
   - Policies are set sequentially again: the ECB internalizes the second-period reaction function of each fiscal player before choosing its policy (π_2), and then national fiscal policies $(\tau_{i,2})$ are selected.

The present section provides equilibrium outcomes and welfare losses for both periods. The details of the calculations are given in the appendix. I shall turn to the issues arising from theses outcomes in the next two sections.

In this setup, the decision regarding how much to spend on infrastructure and other public projects is made in the first period while taking into account the repercussions of these investments on future outcomes. When determining the optimal level of productivity-enhancing public expenditure, the first-period fiscal authorities have to equate the marginal cost from increasing public investment (i.e. larger losses due to the cut in current non-productive spending and to higher inflation and unemployment in period one) to the (discounted) marginal benefit (i.e. smaller losses in period two owing to lower equilibrium inflation and higher output and public spending). Eq. (6) below represents this intertemporal trade-off:[10]

$$x_1^* + g_1^* + g_1^{I} = \frac{\beta\rho_{G}M}{N}\left(x_2^* + g_2^* - \beta g_1^{I}\right), \tag{6}$$

[9] Notice, however, that the first-period fiscal authorities act as Stackelberg leaders *vis-à-vis* the second-period players, insofar as they affect future economic outcomes when selecting the level of public capital expenditure.

[10] The country subscript is now dropped for notational convenience, as the policy choices and macroeconomic outcomes of each member state are all identical in the equilibrium.

where $M \equiv 2s_g^2\left(1-\frac{1}{\mathrm{n}}\right)+b_\pi\left(1+s_g\right)^2+\frac{4s_\pi s_g^3}{\mathrm{n}b_\pi\left(1+s_g\right)} > 0$ and $N \equiv 2s_g^2+b_\pi\left(1+s_g\right)^2 > 0.$

The left-hand side of Eq. (6) represents the loss sustained by national fiscal authorities in period one in consequence of an increase in public investment spending. Expanding public investment in t = 1 takes place at the expense of lower public consumption expenditure (see Eq. (A.19d) in the appendix: $\partial g_1^{\mathrm{C}}/\partial g_1^{\mathrm{I}} < 0$). So, the higher the public investment level, the higher is the (negative) current spending gap in the first period (i.e. $\partial\left(g_1^{\mathrm{C}}-g_1^*\right)/\partial g_1^{\mathrm{I}} < 0$). Any increase in public capital expenditure implies higher distortionary taxes levied on production (see (A.19b): $\partial\tau_1/\partial g_1^{\mathrm{I}} > 0$). This increase in taxation reduces profitability and has a direct adverse effect on output (which is always below its target in the equilibrium), so the incentive for the central bank to inflate becomes greater (see (A.19a) and (A.19c): $\partial\pi_1/\partial g_1^{\mathrm{I}} > 0$ and $\partial x_1/\partial g_1^{\mathrm{I}} < 0$).

The right-hand side of Eq. (6) represents the benefit in the next period from undertaking public investments today. $\beta\rho_{\mathrm{G}}M/N$ is the *effective* discount factor of fiscal authorities. This term varies in accordance with the nature of the policy game (i.e. the commitment technology available to players) and depends both on the relative preferences of fiscal and monetary authorities, as measured by s_π, s_g and b_π, and on the size of the monetary union, n. The higher the level of public investment spending, the better will be macroeconomic performance in the final period. Any increase in public capital expenditure in t = 1 allows the second-period output to be higher by improving productivity (see Eq. (A.20c) in the appendix: $\partial x_2/\partial g_1^{\mathrm{I}} > 0$). Public investment in the first period thereby expands the amount of resources available to fiscal authorities in the future (see (A.20b): $\partial\tau_2/\partial g_1^{\mathrm{I}} > 0$) and thus enables them to reduce the deviation of public consumption spending from its target value in the next period (i.e. $\partial\left(g_2^{\mathrm{C}}-g_2^*\right)/\partial g_1^{\mathrm{I}} > 0$ according to (A.20d)). Given the higher employment level in t = 2, the incentive for the ECB to create surprise inflation is weakened, so the equilibrium inflation rate in t = 2 negatively depends on public capital expenditure (see (A.20a): $\partial\pi_2/\partial g_1^{\mathrm{I}} < 0$).

One can now solve explicitly for the equilibrium level of public investment in the Stackelberg game from Equation (6):

$$\left(g_1^{\mathrm{I}}\right)^{\mathrm{ML}} = \frac{\left(\rho_{\mathrm{G}}\right)^{\mathrm{ML}}\left(x_2^*+g_2^*\right)-\left(x_1^*+g_1^*\right)}{1+\beta\left(\rho_{\mathrm{G}}\right)^*}, \tag{7}$$

where $\left(\rho_{\mathrm{G}}\right)^{\mathrm{ML}} \equiv \frac{\beta\rho_{\mathrm{G}}M}{N}$, and where the superscript "ML" indicates monetary leadership.

The right-hand side of Eq. (7) reveals the determinants of public investment. The higher the first-period output and current spending targets, the lower the optimal share of productive spending (i.e. $\partial(g_1^{\mathrm{I}})^{\mathrm{ML}}/\partial(x_1^*+g_1^*) < 0$). Conversely, the higher are the second-period output and government consumption spending targets, the higher must be the level of public capital expenditure in period one (i.e. $\partial(g_1^{\mathrm{I}})^{\mathrm{ML}}/\partial(x_2^*+g_2^*) > 0$). It is also straightforward to see that a higher effective discount factor raises the marginal benefit of public investment and thus entails an increase in public capital expenditure in the first period (i.e. $\partial(g_1^{\mathrm{I}})^{\mathrm{ML}}/\partial\left(\rho_{\mathrm{G}}\right)^* > 0$). In other words, public investment drops whenever impatience grows.

Substituting (7) for g_1^{I} into Eqs. (A.19a), (A.19c) and (A.19d) in the appendix gives the first-period equilibrium values for inflation, output and public consumption spending:

$$\pi_1^{\mathrm{ML}} = \frac{2s_g^2(\rho_{\mathrm{G}})^{\mathrm{ML}}C}{N\left(1+\beta(\rho_{\mathrm{G}})^{\mathrm{ML}}\right)}, \tag{8a}$$

$$\left(x_1 - x_1^*\right)^{\mathrm{ML}} = -\frac{b_\pi s_g\left(1+s_g\right)(\rho_{\mathrm{G}})^{\mathrm{ML}}C}{N\left(1+\beta(\rho_{\mathrm{G}})^{\mathrm{ML}}\right)}, \tag{8b}$$

$$\left(g_1^{\mathrm{C}} - g_1^*\right)^{\mathrm{ML}} = -\frac{b_\pi\left(1+s_g\right)(\rho_{\mathrm{G}})^{\mathrm{ML}}C}{N\left(1+\beta(\rho_{\mathrm{G}})^{\mathrm{ML}}\right)}, \tag{8c}$$

where $C \equiv \beta\left(x_1^* + g_1^*\right) + \left(x_2^* + g_2^*\right) > 0$.

By substituting (7) for g_1^{I} into Eqs. (A.20a), (A.20c) and (A.20d) in the appendix, one then arrives at the second-period equilibrium values:

$$\pi_2^{\mathrm{ML}} = \frac{2s_g^2 C}{N\left(1+\beta(\rho_{\mathrm{G}})^{\mathrm{ML}}\right)}, \tag{9a}$$

$$\left(x_2 - x_2^*\right)^{\mathrm{ML}} = -\frac{b_\pi s_g\left(1+s_g\right)C}{N\left(1+\beta(\rho_{\mathrm{G}})^{\mathrm{ML}}\right)}, \tag{9b}$$

$$\left(g_2^{\mathrm{C}} - g_2^*\right)^{\mathrm{ML}} = -\frac{b_\pi\left(1+s_g\right)C}{N\left(1+\beta(\rho_{\mathrm{G}})^{\mathrm{ML}}\right)}. \tag{9c}$$

In this dynamic setup, the expression for society's welfare loss in the equilibrium can be split in several terms so as to distinguish the *intratemporal* component from the *intertemporal* one:

$$V^{\mathrm{S}} = L_1^{\mathrm{S}} + \rho_{\mathrm{S}} L_2^{\mathrm{S}} = \left(L^{\mathrm{S}}\right)_{\mathrm{intra}} \times \left(L^{\mathrm{S}}\right)_{\mathrm{inter}} \times C^2. \tag{10a}$$

The intratemporal loss, $\left(L^{\mathrm{S}}\right)_{\mathrm{intra}}$, represents the distribution of distortions due to the leadership of monetary authorities and the lack of commitment across the various available policy instruments within each period, and then corresponds to the result that would be obtained in a simple one-shot game. The intertemporal loss, $\left(L^{\mathrm{S}}\right)_{\mathrm{inter}}$, stems from the distribution of distortions between the two periods and hence depends on the rate of time preference.

By making use of the two systems of equations (8) and (9) above, one finds:

$$\left(L^{\mathrm{S}}\right)_{\mathrm{intra}}^{\mathrm{ML}} = \frac{s_g\left(4s_\pi s_g^3 + b_\pi^2\left(1+s_g\right)^3\right)}{2N^2}, \tag{10b}$$

$$\left(L^{\mathrm{S}}\right)_{\mathrm{inter}}^{\mathrm{ML}} = \frac{\rho_{\mathrm{S}} + \left((\rho_{\mathrm{G}})^{\mathrm{ML}}\right)^2}{\left[1+\beta(\rho_{\mathrm{G}})^{\mathrm{ML}}\right]^2}. \tag{10c}$$

In what follows, I shall use the intratemporal factor to investigate whether the establishment or the enlargement of the monetary union can lead to a drop in public investment, whereas the intertemporal factor will be considered to identify the cases in which public capital spending is excessive or, on the contrary, insufficient from a social standpoint.

4. Intratemporal losses and optimal central banker

This section mainly explores the formal conditions under which monetary unification can involve a fall in public capital expenditure. This question however implies to study concurrently the normative issue of the optimally designed monetary institution for the whole union. Hence, the first step is to determine the type of central banker to whom the common monetary policy should be delegated. The optimal central banker formally corresponds to the degree of inflation aversion in the monetary loss function (5), b_π, which makes it possible to minimize the intratemporal loss factor (10b):

$$(b_\pi)^{\mathrm{ML}} = \frac{2s_\pi s_g}{1+s_g}. \tag{11}$$

This result makes it possible to formulate the first proposition below:

Proposition 1. *In the Stackelberg game with discretionary monetary leadership, the common central banker minimizing intratemporal welfare losses is conservative whenever governments put a greater weight on the current (non-productive) public spending objective than on output (i.e. $s_g > 1$), and anticonservative whenever the weight of the output objective exceeds that of the current spending objective (i.e. $s_g < 1$).*

The reason for this result is the following. Fiscal authorities are logically induced to set a lower tax rate whenever they put a larger weight on output and employment. There is then less incentive for the central bank to create surprise inflation in order to stimulate economic activity. In such a case, at $b_\pi = s_\pi$, the union's inflation rate is too low from the participating countries' standpoint, given the social value of seigniorage in providing public revenues. The public consumption spending objective then implies that the tax cut has to be offset by a higher inflation rate. Accordingly, by making the common central banker less conservative than governments, welfare gains can be reaped. In the reverse case in which governments attach relatively more importance to their current spending objective, the rise in distortionary taxes has an adverse impact on output and pushes the central bank into running a more expansionary monetary policy. It follows that the equilibrium inflation rate is excessive at $b_\pi = s_\pi$. The best is therefore to choose a Rogoff-type governor, who has a greater dislike for inflation, in order to allow governments to limit the tax increase and the output fall.

The parameter b_π indeed plays an important role in the present analysis because it directly affects the effective discount factor $(\rho_{\mathrm{G}})^{\mathrm{ML}}$. To see this, let us rewrite $(\rho_{\mathrm{G}})^{\mathrm{ML}}$ as follows:

$$(\rho_{\mathrm{G}})^{\mathrm{ML}} \equiv \frac{\beta\rho_{\mathrm{G}}M}{N} = \beta\rho_{\mathrm{G}}\left[1+\frac{2s_g^2}{\mathrm{n}N}\left(\frac{2s_\pi s_g}{b_\pi(1+s_g)}-1\right)\right]. \tag{12}$$

It is straightforward to see that the second term in brackets in the right-hand side of the expression above, $[2s_\pi s_g/[b_\pi(1+s_g)]-1]$, vanishes if and only if the common monetary policymaker is endowed with the optimal relative weight of the price stability objective given by (11) (i.e. $b_\pi = 2s_\pi s_g/(1 + s_g)$). Consequently, the term $2(s_g)^2(\mathrm{n}N)^{-1}[2s_\pi s_g/[b_\pi(1 + s_g)] - 1]$ originates in the distortions due to monetary leadership that involve a suboptimal inflation rate. In the absence of any adjustment of the central banker's trade-off (i.e. $b_\pi = s_\pi$), this term can be either positive or negative, so that the effective discount factor $(\rho_{\mathrm{G}})^{\mathrm{ML}}$ happens to be either increased or reduced. More precisely, at $b_\pi = s_\pi$, the term $2(s_g)^2(\mathrm{n}N)^{-1}[2s_\pi s_g/[b_\pi(1 + s_g)] - 1]$ is positive whenever national governments put a greater weight on the current public spending objective than on output (i.e. $s_g > 1$), whereas it is negative whenever they attach relatively more importance to output and employment (i.e. $s_g < 1$).

Let us first consider the situation in which governments favor the objective of reaching the targeted level of public consumption spending. If $s_g > 1$, the equilibrium inflation rate turns out to be excessive since the socially optimal central banker is conservative, as seen before. Therefore, from the *ex ante* perspective of the first-period fiscal players, inflation expectations in period two are too high. The present national governments are then induced to spend more on infrastructure and education to improve overall productivity and to promote economic growth in the long run. In this model, devoting more resources for productive uses in period one makes it possible to boost activity in period two, which weakens the incentive for the ECB to inflate in the final period. The incentive from present policymakers to reduce the credibility problem and to alleviate the inflation bias in the future is formally captured by the term $2(s_g)^2(\mathrm{n}N)^{-1}[2s_\pi s_g/[b_\pi(1 + s_g)] - 1]$ in (12), which represents a *credibility-improving* effect here. As this term is strictly positive and then raises the effective discount factor, the optimal level of public investment indeed goes up.

When governments put a larger weight on the output objective than on the current spending objective (i.e. $s_g < 1$), the equilibrium inflation rate is, on the contrary, too low, since the socially optimal monetary decision-maker is weight-liberal in such a case (see (11)). Accordingly, from the *ex ante* perspective of the first-period fiscal authorities, expected inflation in period two turns out to be insufficient. The first-period governments then have an incentive to reduce public capital expenditure for compelling the ECB to run a more expansionary policy in period two. The term $2(s_g)^2(\mathrm{n}N)^{-1}[2s_\pi s_g/[b_\pi(1 + s_g)] - 1]$ now represents a *credibility-damaging* effect; it is strictly negative at $b_\pi = s_\pi$ and hence reduces the effective discount factor $(\rho_{\mathrm{G}})^{\mathrm{ML}}$, which makes that the optimal share of public resources devoted to productive investment declines.

Proposition 2 recapitulates:

Proposition 2. *In the absence of any adjustment of the common central banker's output-inflation trade-off (i.e. $b_\pi = s_\pi$), the first-period governments are strategically induced to increase productivity-enhancing public expenditure if they attach relatively more importance to the public consumption spending objective than to the output objective (in order to alleviate the credibility problem in the second period), but they are induced to cut public capital spending whenever they put a larger weight on output and employment than on current spending (in order to aggravate the credibility problem in period two).*

The argument above holds in a closed economy as well as in a monetary union. Nevertheless, within a monetary union, the magnitude of this positive or negative credibility effect crucially depends on the number of member states, n. This is because the anti-inflationary credibility of the common monetary policy is like a public good. In the euro area, the incentive for each participating country to contribute to this public good, by setting the appropriate public investment policy, depends much on the *ex ante* perceived effects of its own measures on the medium or long-term orientation of the ECB's monetary strategy. The consequences of domestic choices for the common inflation rate will be more or less important according to the number of member states (see Eqs. (A.3) and (A.11) in the appendix). As the ECB considers an equally weighted average of the national output objectives, its reaction to a change in the public investment level of any country i (i = 1,…, n) is indeed only 1/n-th of the corresponding change observed under national monetary policymaking (i.e. n = 1). The larger the monetary union (i.e. n → ∞), the smaller are the perceived effects of any change in national public investment policy on future inflation expectations. Therefore, each fiscal authority taken separately is less prone to reassess the composition of public spending in a larger monetary union.

When $s_g > 1$, inflation expectations are too high in the absence of any adjustment of the central banker's preferences, as seen above. A rise in n, corresponding either to the establishment of the monetary union or to the enlargement of the union, involves a decrease in the credibility-improving factor (i.e. $\partial[2(s_g)^2(\mathrm{n}N)^{-1}[2s_\pi s_g/[b_\pi(1+s_g)]-1]]/\partial\mathrm{n} < 0$), and hence in the effective discount factor $(\rho_{\mathrm{G}})^{\mathrm{ML}}$. Each national fiscal decision-maker has less incentive to increase public capital expenditure in period one for alleviating the common anti-inflationary credibility problem in period two, as the perceived beneficial effects of refocusing public spending towards more productive investments in terms of lower inflation in the future become smaller. Consequently, the monetary union leads to a fall in public investment when the relative weight on the current spending objective is higher than that on output.

If $s_g < 1$, inflation expectations are, on the contrary, too low. A rise in n then involves a lower credibility-damaging effect (i.e. $\partial[2(s_g)^2(\mathrm{n}N)^{-1}[2s_\pi s_g/[b_\pi(1+s_g)]-1]]/\partial\mathrm{n} > 0$) and an increase in the effective discount factor. Accordingly, each national government has less incentive to reduce its expenditure in infrastructure projects and other public services for stimulating the incentive for the central bank to inflate in the second period. The perceived effect of a cut in public investment spending in the first period on the future union's inflation rate is smaller. Contrary to the preceding case, public investment now turns out to be higher in a monetary union than with national monetary policymaking.

The third proposition below recapitulates our main result:

Proposition 3. *In the absence of any adjustment of the central bank's output-inflation trade-off (i.e. $b_\pi = s_\pi$), monetary unification (i.e. a rise in* n*) leads to a drop in public investment if governments mainly attach importance to the current spending objective (i.e. $s_g > 1$), and to an increase in public investment if they favor the output objective (i.e. $s_g < 1$).*

Up to now, it has been assumed for simplicity that the ratio of real money holdings to non-distortionary output is equal to unity. In other words, inflation maps into seigniorage revenues one-for-one. It should be recognized that this assumption is not necessarily the most realistic. The seigniorage revenue within the euro area, and more generally in developed countries, does not constitute a very large component of governments' receipts. As money holdings become smaller in modern economies with efficient means of payment, inflation yields less seigniorage. If the present model is intended to represent the EMU, the most likely case is then that of an excessive equilibrium inflation rate because the social value of seigniorage is not strong enough to make up for the familiar distortion due to the lack of commitment and self-defeating incentives to boost activity. The optimal central banker must therefore be conservative. Hence, this strategic framework suggests that an EMU enlargement might reduce the credibility-improving effect and lead to a fall in public capital expenditure, the more so that seigniorage revenues in transition economies in Central and Eastern Europe are not much different from those observed in developed economies in recent years. Conversely, in developing countries where inflationary finance remains important, the socially optimal inflation rate is presumably higher; in such a case, according to the present model, a project of monetary unification could theoretically promote public investment by reducing the credibility-damaging factor.

Proposition 4 summarizes this point:

Proposition 4. *Given the possibility of a strategic use of public investment policy, monetary unification between economies where seigniorage revenues tend to be negligible may entail a fall in productive public spending, whereas monetary unification between economies where inflationary finance is important may promote public investment.*

It is worth noting that the result about the possibility of a fall in public investment within the EMU is here closely linked to strategic reasons. No particular assumption has been made concerning the fiscal rules imposed in the EU by the Maastricht criteria and the SGP. Besides, the link between the marked drop in government investment spending during the nineties and the deficit limits laid down in the Maastricht Treaty is not clear-cut (European Commission, 2003). At first glance, however, it is arguable, at least in theory, that the requirement of fiscal discipline in Europe might entail larger cuts in public investment spending than in public consumption spending, especially for short-sighted authorities discounting future events at a high rate. Indeed, cutting public consumption spending may be politically costly, whereas public investment spending can be delayed with limited political damage. The present model simply suggests that such a result can partly be explained by other reasons.

5. Intertemporal losses and optimal level of productive spending

It has been established in Section 4 that monetary unification can in theory encourage as well as discourage public investment, according to the relative preferences of national governments, or depending whether seigniorage is important or not, as seen in Proposition 4. Let us now turn to the normative issue of the welfare implications of these upward or downward variations in public investment. To that end, we have to consider the intertemporal loss factor. It can easily be shown from (10c) that:

$$\frac{\partial\left(L^{\mathrm{S}}\right)^{\mathrm{ML}}_{\mathrm{inter}}}{\partial\left(\rho_{\mathrm{G}}\right)^{\mathrm{ML}}}\begin{Bmatrix}>\\=\\<\end{Bmatrix}0 \Rightarrow \frac{\rho_{\mathrm{G}}M}{N}\begin{Bmatrix}>\\=\\<\end{Bmatrix}\rho_{\mathrm{S}}. \tag{13}$$

At first, consider the simplest case in which governments are benevolent, in the sense that they have the same time preference rate as societies (i.e. $\rho_{\mathrm{G}} = \rho_{\mathrm{S}}$), and in which the common central banker is already endowed with the price stability weight that minimizes the intertemporal loss factor (i.e. $b_{\pi} = 2s_{\pi}s_{g}/(1 + s_{g})$). Hence, $M/N = 1$ and the first-order condition (13) is equal to zero: the distribution of distortions between the two periods of the game is then optimal and the intertemporal loss factor is minimized, too. In the absence of any political distortion (i.e. when fiscal authorities are not short-sighted), the adjustment of the output-inflation trade-off in the monetary policymaker's loss function is enough to maximize social welfare. Intuitively, whenever there are only (intratemporal) distortions originating in the interaction between fiscal and monetary policies and leading to either excessive or insufficient inflation, the adjustment of the central banker's trade-off fully resolves the problem.

In contrast, if there are also political distortions, the first-order condition (13) cannot be equal to zero. As $\rho_\mathrm{G} < \rho_\mathrm{S}$, $\partial\left(L^\mathrm{S}\right)^\mathrm{ML}_\mathrm{inter}/\partial\left(\rho_\mathrm{G}\right)^\mathrm{ML} < 0$. Hence, the effective discount factor is too small since an increase in this factor involves a decrease in the intertemporal loss, which means that the public investment level always turns out to be insufficient whenever the first-period fiscal players are myopic, even if intratemporal losses are minimized. The decision-makers' higher rate of time preference indeed introduces a natural bias towards larger public consumption expenditure in the first period; the immediate cost of undertaking public investments goes up, whereas the perceived beneficial effects of these investments in the final period lessen.

Proposition 5 recapitulates:

Proposition 5. *In the presence of political imperfections (i.e.* $\rho_\mathrm{G} < \rho_\mathrm{S}$*), intertemporal welfare losses are not minimized, even if the common central banker is endowed with the price stability weight that allows intratemporal losses to be minimized. The myopic behavior of the incumbent governments makes that the public investment level is always too low from a social standpoint.*

Another question of interest concerns the welfare implications of the credibility-improving or damaging effect in the absence of any adjustment of the central banker's output-inflation trade-off. The equilibrium level of public investment is insufficient with respect to the social optimum if $\partial\left(L^\mathrm{S}\right)^\mathrm{ML}_\mathrm{inter}/\partial\left(\rho_\mathrm{G}\right)^\mathrm{ML} < 0$, or $\rho_\mathrm{G}M/N < \rho_\mathrm{S}$. By making use of (12), at $b_\pi = s_\pi$, the condition for public underinvestment within the monetary union can be expressed formally as:

$$\frac{2s_g^2\left(s_g - 1\right)}{\mathrm{n}N\left(1 + s_g\right)} < \frac{\rho_\mathrm{S} - \rho_\mathrm{G}}{\rho_\mathrm{G}}. \qquad (14)$$

To begin with, consider the case in which national governments mainly attaches importance to the output objective (i.e. $s_g < 1$). The left-hand side of the inequality above is then negative, so the inequality is always checked. Thus, whatever the fiscal authorities' subjective discount factor, there is always public underinvestment in the monetary union. Interestingly, even in the absence of any political imperfection making governments short-sighted, the effective discount factor is always too low and public capital expenditure turns out to be insufficient from a social point of view. This is because monetary leadership involves an excessive decrease in the equilibrium inflation rate in this case. Hence, the first-period fiscal players are systematically induced to cut spending in infrastructure projects and other public services in order to compel the central bank to run a more expansionary policy in the future.

However, as an enlargement of the monetary union then stimulates public investment, by lessening the credibility-damaging effect, intertemporal welfare losses are all the same lower than under insular monetary policymaking. In fact, in this case, the larger the number of member states, the smaller are the credibility-damaging effect and the intertemporal loss factor. More largely, as intratemporal losses do not depend on n (see (10b)), any enlargement of the monetary union necessarily makes countries better off, so the optimal size of the union is infinite.

Proposition 6 summarizes this point:

Proposition 6. *In the absence of any adjustment of the common central banker's output-inflation trade-of, public investment in the monetary union always turns out to be insufficient from a social standpoint whenever governments put a greater weight on the output objective* *than on the current public spending objective, even if they are not myopic. In this case, any enlargement of the monetary union is welfare improving, so the optimal size of the union is infinite.*

Now consider the situation in which fiscal authorities put a larger weight on public consumption than on output (i.e. $s_g > 1$). The left-hand side of (14) becomes positive, so two cases have to be distinguished. If governments are not short-sighted and share the same rate of time preference as societies, the right-hand side is equal to zero, so the inequality cannot hold. In other words, monetary leadership leads to public overinvestment, which is also harmful to welfare. The strategic incentive from fiscal players to increase public capital expenditure with the aim of reducing the monetary authorities' anti-inflationary credibility problem in the future is then not weakened by a higher rate of time preference. On the other hand, in the presence of political distortions, (14) can be checked or not, depending on the importance of these distortions, $\rho_S - \rho_G$, and on the size of the monetary union, n, among others. Even if governments are myopic, public investment can remain excessive, especially if the number of participating countries is not very high. In contrast, as soon as the myopic behavior of national political authorities becomes more pronounced (i.e. $\rho_S - \rho_G \to 1$), or as soon as the monetary union consists of a sufficiently large number of participating countries (i.e. $n \to \infty$), the public investment level is likely to be too low. In particular, within a very large monetary union, the credibility-improving factor almost vanishes because the perceived impact of a higher national level of public capital expenditure becomes insignificant.

Contrary to the previous case, the welfare implications of an EMU enlargement now appear to be uncertain. As $s_g > 1$, any entry of new member states involves a decrease in public investment. In the absence of political distortions, this enlargement enhances welfare by reducing public overinvestment and, hence, intertemporal losses. In contrast, in a world with important political imperfections, or, more generally, as soon as public investment is too low with respect to the social optimum, an enlargement negatively impacts on welfare because it further deters national authorities from undertaking public investments. In such a case, the optimal size of the union is finite.

The proposition below recapitulates:

Proposition 7. *In the absence of any adjustment of the central bank's output-inflation trade-off, public investment in the monetary union can be either excessive or insufficient from a social point of view if governments put a greater weight on the current spending objective than on output, depending on the degree of myopia and the number of member states. In consequence, any enlargement of the union may reduce or increase welfare losses.*

6. Conclusion

This paper has discussed within a game-theoretic framework how monetary unification can affect the participating countries' public investment level, in parallel with the issue of the socially optimal monetary arrangement. The assumption of a strategic use of public investment policy implies that the composition of overall government spending depends both on the nature of the policy game among decision-makers and on future inflation expectations. Thus, whenever the union's inflation rate is not socially optimal, in the absence of any adjustment of the central banker's preferences, national fiscal authorities are induced to reappraise their investment strategy with the aim of getting closer to the optimum, by altering the orientation of monetary policy in the future. However, in a monetary union, the effort of each national government, taken separately, is conditioned by the *ex ante* perceived consequential effects of its own measures on the future inflation rate. In particular, if the equilibrium inflation rate turns out to be excessive, the incentive to undertake public investments for boosting output and reducing the temptation to inflate may be weakened quite appreciably. Hence, the model suggests that an enlargement of the EMU to Central and Eastern Europe may entail cuts in infrastructure spending on purely strategic grounds, irrespective of the fiscal rules imposed by the SGP.

The other question of interest turns on the welfare implications of such a change in the public investment level. The consequential effects of an enlargement of the EMU appear to be ambiguous. If the common central banker is endowed with the price stability weight that minimizes intratemporal distortions, public investment happens to be systematically insufficient from a social point of view as soon as governments are myopic. In the absence of any adjustment of the central banker's output-inflation trade-off, there can be either underinvestment or overinvestment, depending on the relative preferences of fiscal authorities, the degree at which they discount future events and the number of member countries. It follows that any enlargement of the monetary union may reduce or increase intertemporal distortions. Somewhat surprisingly, the model shows that the amount of productive public spending is always too small when governments favor output and employment. The reason is that discretionary monetary leadership involves a too contractionary monetary policy in such a case, so that governments are pushed into cutting public capital expenditure for compelling the common central bank to adopt a less restrictive stance in the future. In such a case, an enlargement of the monetary union makes member countries better off owing to the diminution in intertemporal losses. On the other hand, when the objective of reaching the current public spending target prevails, public investment can be excessive even in the absence of political imperfections, because monetary leadership then entails a too expansionary monetary policy.

Appendix. Derivation of the equilibrium level of public investment and welfare losses under a monetary union

Both fiscal and monetary policies are discretionary and implemented after the setting of inflation expectations by the private sector. In each period, monetary policy is announced and set first; the common central bank acts as the leader in the game and internalizes the best-response function of every national fiscal authority.

The two-period model is solved by backward induction. To begin with, the fiscal authority of country *i* (*i* = 1,..., n) selects $\tau_{i,\,2}$ to minimize the loss $L^{\mathrm{G}}_{i,\,2}$ subject to the budget constraint and the output supply function for t = 2, taking as given $g^{\mathrm{I}}_{i,1}, \pi_2, \pi^{\mathrm{e}}_2$ and the other national fiscal policies. The second-period reaction function of country *i* is then:

$$\tau_{i,\,2} = \frac{(1 - s_g)\pi_2 - \pi^{\mathrm{e}}_2 - x^*_2 + s_g g^*_2 + \beta g^{\mathrm{I}}_{i,1}}{1 + s_g}. \tag{A.1}$$

The central bank takes into account the best-response function above for i = 1,..., n. Substitute (A.1) into the monetary policymaker's objective function for t = 2. The monetary player therefore has to minimize the following loss with respect to π_2:

$$L_2^{\mathrm{M}} = \frac{b_\pi \pi_2^2}{2} + \frac{s_g^2}{2\mathrm{n}(1+s_g)^2} \sum_{j=1}^{\mathrm{n}} \left[2\pi_2 - \pi_2^{\mathrm{e}} - \left(x_2^* + g_2^*\right) + \beta g_{j,1}^{\mathrm{I}}\right]^2. \tag{A.2}$$

Given that rational expectations imply $\pi_2 = \pi_2^{\mathrm{e}}$ *ex post*, one has:

$$\pi_2 = \frac{2s_g^2\left(x_2^* + g_2^* - \dfrac{\beta}{\mathrm{n}} \sum_{j=1}^{\mathrm{n}} g_{j,1}^{\mathrm{I}}\right)}{2s_g^2 + b_\pi (1+s_g)^2}. \tag{A.3}$$

Then, the first-order condition for $\tau_{i,2}$ can be rewritten as:

$$\begin{aligned}\tau_{i,2} = &-\frac{\left(2s_g^2 + b_\pi(1+s_g)\right)x_2^*}{2s_g^2 + b_\pi(1+s_g)^2} + \frac{b_\pi s_g (1+s_g) g_2^*}{2s_g^2 + b_\pi(1+s_g)^2} + \frac{\beta g_{i,1}^{\mathrm{I}}}{1+s_g} \\ &+ \frac{\dfrac{2\beta s_g^3}{\mathrm{n}} \sum_{j=1}^{\mathrm{n}} g_{j,1}^{\mathrm{I}}}{(1+s_g)\left[2s_g^2 + b_\pi(1+s_g)^2\right]}.\end{aligned} \tag{A.4}$$

By making use of (A.3) and (A.4), one derives country i's output and spending gaps:

$$x_{i,2} - x_2^* = -\frac{b_\pi s_g (1+s_g)(x_2^* + g_2^*)}{2s_g^2 + b_\pi(1+s_g)^2} + \frac{\beta s_g g_{i,1}^{\mathrm{I}}}{1+s_g} - \frac{\dfrac{2\beta s_g^3}{\mathrm{n}} \sum_{j=1}^{\mathrm{n}} g_{j,1}^{\mathrm{I}}}{(1+s_g)\left[2s_g^2 + b_\pi(1+s_g)^2\right]}, \tag{A.5}$$

$$g_{i,2}^{\mathrm{C}} - g_2^* = -\frac{b_\pi (1+s_g)(x_2^* + g_2^*)}{2s_g^2 + b_\pi(1+s_g)^2} + \frac{\beta g_{i,1}^{\mathrm{I}}}{1+s_g} - \frac{\dfrac{2\beta s_g^2}{\mathrm{n}} \sum_{j=1}^{\mathrm{n}} g_{j,1}^{\mathrm{I}}}{(1+s_g)\left[2s_g^2 + b_\pi(1+s_g)^2\right]}. \tag{A.6}$$

As $\left(x_{i,2} - x_2^*\right) = s_g\left(g_{i,2}^{\mathrm{C}} - g_2^*\right)$, $L_{i,2}^{\mathrm{G}} = \dfrac{s_\pi \pi_2^2}{2} + \dfrac{s_g(1+s_g)\left(g_{i,2}^{\mathrm{C}} - g_2^*\right)^2}{2}$. Hence, government i's losses in t = 2 for a given level of public investment are:

$$L_{i,2}^{\mathrm{G}} = \frac{2s_\pi s_g^4\left(x_2^* + g_2^* - \frac{\beta}{\mathrm{n}}\sum_{j=1}^{\mathrm{n}} g_{j,1}^{\mathrm{I}}\right)^2}{\left[2s_g^2 + b_\pi\left(1+s_g\right)^2\right]^2} + \frac{s_g\left(1+s_g\right)}{2}\times$$
$$\left[-\frac{b_\pi\left(1+s_g\right)\left(x_2^* + g_2^*\right)}{2s_g^2 + b_\pi\left(1+s_g\right)^2} + \frac{\beta g_{i,1}^{\mathrm{I}}}{1+s_g} - \frac{\frac{2\beta s_g^2}{\mathrm{n}}\sum_{j=1}^{\mathrm{n}} g_{j,1}^{\mathrm{I}}}{\left(1+s_g\right)\left[2s_g^2 + b_\pi\left(1+s_g\right)^2\right]}\right]^2. \tag{A.7}$$

In period one, government i ($i = 1,..., \mathrm{n}$) considers the following function:

$$L_{i,1}^{\mathrm{G}} + \rho_{\mathrm{G}} L_{i,2}^{\mathrm{G}} = \frac{1}{2}\left\{s_\pi \pi_1^2 + \left(\pi_1 - \pi_1^{\mathrm{e}} - \tau_{i,1} - x_1^*\right)^2 + s_g\left(\pi_1 + \tau_{i,1} - g_{i,1}^{\mathrm{I}} - g_1^*\right)^2\right\}$$
$$+\frac{2\rho_{\mathrm{G}} s_\pi s_g^4\left(x_2^* + g_2^* - \frac{\beta}{\mathrm{n}}\sum_{j=1}^{\mathrm{n}} g_{j,1}^{\mathrm{I}}\right)^2}{\left[2s_g^2 + b_\pi\left(1+s_g\right)^2\right]^2} + \frac{\rho_{\mathrm{G}} s_g\left(1+s_g\right)}{2}\times \tag{A.8}$$
$$\left[-\frac{b_\pi\left(1+s_g\right)\left(x_2^* + g_2^*\right)}{2s_g^2 + b_\pi\left(1+s_g\right)^2} + \frac{\beta g_{i,1}^{\mathrm{I}}}{1+s_g} - \frac{\frac{2\beta s_g^2}{\mathrm{n}}\sum_{j=1}^{\mathrm{n}} g_{j,1}^{\mathrm{I}}}{\left(1+s_g\right)\left[2s_g^2 + b_\pi\left(1+s_g\right)^2\right]}\right]^2,$$

where ρ_{G} is the subjective discount factor of fiscal authorities.

The same method applies in t = 1. Player i sets its tax rate according to the following reaction function, taking as given $\pi_1, \pi_1^{\mathrm{e}}$ and the fiscal policy choices of the other member states:

$$\tau_{i,1} = \frac{\left(1-s_g\right)\pi_1 - \pi_1^{\mathrm{e}} - x_1^* + s_g\left(g_1^* + g_{i,1}^{\mathrm{I}}\right)}{1+s_g}. \tag{A.9}$$

Substituting the equation above into the central banker's loss function yields:

$$L_1^{\mathrm{M}} = \frac{b_\pi \pi_1^2}{2} + \frac{s_g^2}{2\mathrm{n}\left(1+s_g\right)^2}\sum_{j=1}^{\mathrm{n}}\left[2\pi_1 - \pi_1^{\mathrm{e}} - \left(x_1^* + g_1^*\right) - g_{j,1}^{\mathrm{I}}\right]^2. \tag{A.10}$$

Minimizing this function with respect to π_1 and imposing the rational expectations condition ($\pi_1 = \pi_1^{\mathrm{e}}$ *ex post*) yields equilibrium inflation for a given level of productive public expenditure:

$$\pi_1 = \frac{2s_g^2\left(x_1^* + g_1^* + \frac{1}{\mathrm{n}}\sum_{j=1}^{\mathrm{n}} g_{j,1}^{\mathrm{I}}\right)}{2s_g^2 + b_\pi\left(1+s_g\right)^2}. \tag{A.11}$$

Substitute (A.11) into the first-order condition (A.9) for $\tau_{i,1}$ to yield:

$$\tau_{i,1} = -\frac{\left(2s_g^2 + b_\pi\left(1+s_g\right)\right)x_1^*}{2s_g^2 + b_\pi\left(1+s_g\right)^2} + \frac{b_\pi s_g\left(1+s_g\right)g_1^*}{2s_g^2 + b_\pi\left(1+s_g\right)^2} + \frac{s_g g_{i,1}^{\mathrm{I}}}{1+s_g}$$
$$-\frac{\frac{2s_g^3}{\mathrm{n}}\sum_{j=1}^{\mathrm{n}} g_{j,1}^{\mathrm{I}}}{\left(1+s_g\right)\left[2s_g^2 + b_\pi\left(1+s_g\right)^2\right]}. \tag{A.12}$$

Combine (A.11) and (A.12) with the output supply function and the government budget constraint in the main text to obtain country i's output and spending gaps for t = 1:

$$x_{i,1} - x_1^* = -\frac{b_\pi s_g\left(1+s_g\right)\left(x_1^* + g_1^*\right)}{2s_g^2 + b_\pi\left(1+s_g\right)^2} - \frac{s_g g_{i,1}^{\mathrm{I}}}{1+s_g} + \frac{\frac{2s_g^3}{\mathrm{n}}\sum_{j=1}^{\mathrm{n}} g_{j,1}^{\mathrm{I}}}{\left(1+s_g\right)\left[2s_g^2 + b_\pi\left(1+s_g\right)^2\right]}, \tag{A.13}$$

$$g_{i,1}^{\mathrm{C}} - g_1^* = -\frac{b_\pi\left(1+s_g\right)\left(x_1^* + g_1^*\right)}{2s_g^2 + b_\pi\left(1+s_g\right)^2} - \frac{g_{i,1}^{\mathrm{I}}}{1+s_g} + \frac{\frac{2s_g^2}{\mathrm{n}}\sum_{j=1}^{\mathrm{n}} g_{j,1}^{\mathrm{I}}}{\left(1+s_g\right)\left[2s_g^2 + b_\pi\left(1+s_g\right)^2\right]}. \tag{A.14}$$

As $\left(x_{i,1} - x_1^*\right) = s_g\left(g_{i,1}^{\mathrm{C}} - g_1^*\right)$, $L_{i,1}^{\mathrm{G}} = \frac{s_\pi \pi_1^2}{2} + \frac{s_g\left(1+s_g\right)\left(g_{i,1}^{\mathrm{C}} - g_1^*\right)^2}{2}$. Hence:

$$L_{i,1}^{\mathrm{G}} = \frac{2s_\pi s_g^4\left(x_1^* + g_1^* + \frac{1}{\mathrm{n}}\sum_{j=1}^{\mathrm{n}} g_{j,1}^{\mathrm{I}}\right)^2}{\left[2s_g^2 + b_\pi\left(1+s_g\right)^2\right]^2} + \frac{s_g\left(1+s_g\right)}{2}\times$$
$$\left[-\frac{b_\pi\left(1+s_g\right)\left(x_1^* + g_1^*\right)}{2s_g^2 + b_\pi\left(1+s_g\right)^2} - \frac{g_{i,1}^{\mathrm{I}}}{1+s_g} + \frac{\frac{2s_g^2}{\mathrm{n}}\sum_{j=1}^{\mathrm{n}} g_{j,1}^{\mathrm{I}}}{\left(1+s_g\right)\left[2s_g^2 + b_\pi\left(1+s_g\right)^2\right]}\right]^2. \tag{A.15}$$

The optimal level of public investment spending is chosen in t = 1, while taking into account the consequential effects on the second-period welfare loss. The first-order condition for country i (i = 1,…, n) then is $\frac{\partial L_{i,1}^{\mathrm{G}}}{\partial g_{i,1}^{\mathrm{I}}} + \rho_{\mathrm{G}}\frac{\partial L_{i,2}^{\mathrm{G}}}{\partial g_{i,1}^{\mathrm{I}}} = 0$. One finds from (A.8):

$$\frac{b_\pi s_g\left(1+s_g\right)\left(x_1^*+g_1^*\right)}{N}+\frac{s_g g_{i,1}^{\mathrm{I}}}{1+s_g}-\frac{\frac{2s_g^3}{\mathrm{n}}\sum_{j=1}^{n} g_{j,1}^{\mathrm{I}}}{\left(1+s_g\right)N}-\frac{4\beta\rho_{\mathrm{G}} s_\pi s_g^4\left(x_2^*+g_2^*-\frac{\beta}{\mathrm{n}}\sum_{j=1}^{\mathrm{n}} g_{j,1}^{\mathrm{I}}\right)}{\mathrm{n}N^2}$$

$$+\beta\rho_{\mathrm{G}} s_g\left(1-\frac{2s_g^2}{\mathrm{n}N}\right)\left[-\frac{b_\pi\left(1+s_g\right)\left(x_2^*+g_2^*\right)}{N}+\frac{\beta g_{i,1}^{\mathrm{I}}}{1+s_g}-\frac{\frac{2\beta s_g^2}{\mathrm{n}}\sum_{j=1}^{\mathrm{n}} g_{j,1}^{\mathrm{I}}}{\left(1+s_g\right)N}\right]=0, \tag{A.16}$$

where $N \equiv 2s_g^2+b_\pi\left(1+s_g\right)^2>0,$ as defined in the main text.

Since the economies of the model are identical in all respects, all governments make the same policy choices. Therefore, one can impose the condition $g_{i,1}^{\mathrm{I}}=g_{j,1}^{\mathrm{I}}$ (j = 1,…, n) on the equation above. (A.16) can then be rewritten more simply as:

$$x_1^*+g_1^*+g_{i,1}^{\mathrm{I}}=\frac{\beta\rho_{\mathrm{G}}M}{N}\left(x_2^*+g_2^*-\beta g_{i,1}^{\mathrm{I}}\right), \tag{A.17}$$

which is (6) in the main text and where $M \equiv 2s_g^2\left(1-\frac{1}{\mathrm{n}}\right)+b_\pi\left(1+s_g\right)^2+\frac{4s_\pi s_g^3}{\mathrm{n}b_\pi\left(1+s_g\right)}>0.$

Noting $\left(\rho_{\mathrm{G}}\right)^{\mathrm{ML}} \equiv \frac{\beta\rho_{\mathrm{G}}M}{N},$ one can explicitly solve for the equilibrium level of public investment from Eq. (A.17):

$$\left(g_1^{\mathrm{I}}\right)^{\mathrm{ML}}=\frac{\left(\rho_{\mathrm{G}}\right)^{\mathrm{ML}}\left(x_2^*+g_2^*\right)-\left(x_1^*+g_1^*\right)}{1+\beta\left(\rho_{\mathrm{G}}\right)^*}, \tag{A.18}$$

which is (7) in the main text, and where the superscript "ML" denotes monetary leadership. The country index is now dropped, given the equivalence of equilibrium values.

This equivalence implies:

$$\pi_1=\frac{2s_g^2\left(x_1^*+g_1^*+g_1^{\mathrm{I}}\right)}{N}, \tag{A.19a}$$

$$\tau_1=-\frac{\left(2s_g^2+b_\pi\left(1+s_g\right)\right)x_1^*}{N}+\frac{b_\pi s_g\left(1+s_g\right)\left(g_1^*+g_1^{\mathrm{I}}\right)}{N}, \tag{A.19b}$$

$$x_1-x_1^*=-\frac{b_\pi s_g\left(1+s_g\right)\left(x_1^*+g_1^*+g_1^{\mathrm{I}}\right)}{N}, \tag{A.19c}$$

$$g_1^{\mathrm{C}}-g_1^*=-\frac{b_\pi\left(1+s_g\right)\left(x_1^*+g_1^*+g_1^{\mathrm{I}}\right)}{N}, \tag{A.19d}$$

$$\pi_2 = \frac{2s_g^2\left(x_2^* + g_2^* - \beta g_1^{\mathrm{I}}\right)}{N}, \tag{A.20a}$$

$$\tau_2 = \frac{\left(\beta g_1^{\mathrm{I}} - x_2^*\right)\left(2s_g^2 + b_\pi\left(1+s_g\right)\right)}{N} + \frac{b_\pi s_g\left(1+s_g\right)g_2^*}{N}, \tag{A.20b}$$

$$x_2 - x_2^* = -\frac{b_\pi s_g\left(1+s_g\right)\left(x_2^* + g_2^* - \beta g_1^{\mathrm{I}}\right)}{N}, \tag{A.20c}$$

$$g_2^{\mathrm{C}} - g_2^* = -\frac{b_\pi\left(1+s_g\right)\left(x_2^* + g_2^* - \beta g_1^{\mathrm{I}}\right)}{N}. \tag{A.20d}$$

Substituting (A.18) into the two systems of equations (A.19) and (A.20) above yields equilibrium values for t = 1 and t = 2 in the main text.

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