Double Discretion, International Spillovers and the Welfare Implications of Monetary Unification

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Abstract

This paper develops a monetary-fiscal game which stresses the importance of international spillovers and introduces a double (monetary and fiscal) credibility problem. Models that neglect the inability of fiscal policymakers to commit will tend to underestimate the welfare cost of structural distortions. Due to international spillovers, stochastic shocks may be relatively costly in welfare terms, despite the contribution of policy surprises to finance such shocks. The second part of the paper studies the welfare consequences of the monetary union. It is shown that the welfare impact of EMU for Europe is ambiguous, but that EMU is welfare-improving for the US.

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1 Introduction

Economic and monetary union (EMU) in Europe has raised several concerns. One concern, which has been voiced in the United States in particular, that the rest of the world will suffer, either because Europe will become more inward-looking ('Fortress Europe'), or because Europe will start to behave in a more self-confident manner on the world stage, making use of its increased bargaining power in order to reap a larger share of the benefits of international coordination. Therefore, it is of interest to evaluate the welfare consequences of EMU, not only for the euro area itself, but also for third countries. This paper does not presume that Europe will become more inward-looking and/or more self-confident, but analyses the implications of the *essence* of EMU: the joint determination of monetary policy in Europe. Clearly, if a subset of policymakers start to make joint decisions, as in the European Central Bank (ECB), this may affect economic variables and the decisions of other policymakers.

The model in this paper specifies a policy game involving central banks and fiscal authorities. The policy game takes place in a world of three countries. Monetary policy is determined by independent central banks. Initially, both monetary and fiscal policy are determined at the national level in each country. Then two of the three countries decide to form a monetary union. This leads to a situation of a union-wide monetary policy and decentralised fiscal policies set by the member states of the monetary union. The third country does not participate in the monetary union, but is large enough to have a substantial influence on the economy of the monetary union. I investigate how the strategic interactions between policy makers, and the trade-offs they face, are affected by the start of the monetary union. The supply function, which is based on Martin (1997), stresses the importance of cross-border spillovers. I extend Martin's basic model in a number of ways. The model consists of three rather than two countries, fiscal authorities are explicitly modeled, I allow for structural distortions and commitment problems and I provide a (simple) behavioural motivation for the supply curves. The first two extentions make it possible to consider the interactions between monetary and fiscal policymakers and between EMU participants and third countries. The other extensions allow me to conduct a meaningful welfare evaluation.

For the welfare evaluation, this paper uses a framework developed by Beetsma and Bovenberg (1999b). This framework is particularly useful to assess the welfare cost of structural distortions and unanticipated shocks. My assumption that fiscal policymakers cannot commit and the focus on international spillovers in my model add new dimensions to their analysis. First, it turns out that the inability of fiscal policymakers to commit leads to an upward bias in the expected tax rate. Since output is more responsive to the expected tax rate than to a tax surprise, the upward tax bias increases the welfare cost of structural distortions. The implication is that models that neglect the fiscal commitment problem will tend to underestimate the welfare cost of structural distortions. Second, it is shown that the foreign policy response to unanticipated shocks leads to international spillovers, which enhance the need for policy adjustment in the home country. Thus, the foreign policy response to unanticipated shocks increases the welfare cost of these shocks. This stresses the importance of international policy coordination, in particular in the aftermath of unanticipated shocks.

The welfare consequences of EMU for Europe are ambiguous. The intuition is that intra-European spillovers in monetary policy are internalised. The ECB still has an incentive to conduct a beggar-thy-neighbour policy against the United States, but (unlike national central banks before) not within Europe. This reduces the monetary credibility problem in Europe and thus leads to a lower inflation bias, which is welfare-enhancing. At the same time, the euro area authorities lose a policy instrument (the possibility to have different monetary policies in individual euro area countries). This makes it more difficult to attain policy goals, which is welfare-reducing. The welfare impact of EMU on Europe depends on which effect dominates. Interestingly, and contrary to public fears, US welfare should improve as a result of EMU. The reason is that the United States authorities, unlike the euro area authorities, do not lose a policy instrument, while under EMU they suffer less from European beggar-thy-neighbour policies than they did before.

The remainder of this paper is organised as follows. In the next section, I develop a framework for welfare evaluation. I do this by specifying a two-country model for a policy game involving central banks and fiscal authorities. The model stresses the importance of international spillovers. When negative supply shocks occur, countries compete for economic activity through tax cuts and surprise inflation. The analysis takes into account that both monetary and fiscal authorities face a commitment problem. The two-country set-up facilitates an easy intuitive interpretation of the results. In section 3, the model is extended to a three-country version and optimal policies under floating rates and EMU are derived. The framework is used to evaluate the welfare consequences of monetary unification. Section 4 concludes.

2 Benchmark case: A two-country model

In this section, a two-country monetary-fiscal policy game is developed. Apart from being theoretically interesting in itself, the two-country model serves as a benchmark for the analysis of the impact of EMU, using a three-country model, in section 3.

2.1 Output

The world consists of two identical countries. Each country produces a single good and purchasing power parity is assumed to hold. The model focuses on the short run. Output is a function of labour input only. Supply per capita (in log per capita terms) is derived in Appendix A:

$$y_1 = -kt_1^e - (w_1 - p_1 + t_1 - t_1^e) + (w_2 - p_2 + t_2 - t_2^e) + \varepsilon_1, \quad (1a)$$

$$y_2 = -kt_2^e + (w_1 - p_1 + t_1 - t_1^e) - (w_2 - p_2 + t_2 - t_2^e) + \varepsilon_2, \quad (1b)$$

where y_i is per capita output, w_i is the nominal wage, p_i is the general price level, t_i is the rate of a distortionary output tax, t_i^e is the expected output tax rate, k (> 2) is a constant and ε_i is a random supply shock, with $E\varepsilon_i = 0$, $Var(\varepsilon_i) = \sigma^2$, $E\varepsilon_i\varepsilon_j = 0$, for $i, j = 1, 2$, $i \neq j$.[1]

The following is a simple motivation for the supply functions in this paper. Firms are perfectly competitive. The representative firm is a multinational company with production sites in all countries. The firm's decision with respect to output is determined in two steps. In the first step, the firm hires the number of workers in each country which will maximise expected total firm profits. Once contracts have been signed, workers cannot be laid off, nor can more workers be hired. This implies that after firms have hired workers, they cannot adjust the scale of total worldwide production. The second step is that, after shocks have occurred and policies are set, the firm can relocate workers among countries. Firms can relocate their production from one country to another and will choose to increase production in the country that has a lower real wage and output tax rate. This motivation captures the notions that countries compete for economic activity and that firms are less flexible in the short run than in the long run (although the model does not formally distinguish between a short run and a long run).

[1] As shown in Appendix A, output is more responsive to the expected tax rate than to a tax surprise. In order to reflect this, it would be sufficient to assume $k > 1$. However, due to the chosen normalisation of the three-country model in the next section, it will be required to assume $k > 2$ there. The latter assumption will be used throughout the paper.

The above functions for supply per capita have the following characteristics. First, output is negatively correlated with the real wage rate (i.e. a money surprise) and a tax surprise in the home country. Secondly, output is positively correlated with the foreign real wage and a foreign tax surprise. This is how international spillovers enter the model. Finally, output is negatively related to the domestic expected tax rate. Output is more responsive to the *expected* tax rate than to a tax *surprise*. The reason is that workers are hired at an early stage, so that firms are locked in to a certain total supply level (but not to the production location) before taxes are set. Firms lose a degree of freedom between the moment they form expectations on the tax rate and the moment that tax surprises realise. Intuitively, firms are more responsive to the tax environment before they have made substantial investments than after they have done so. In other monetary-fiscal models, taxes enter the supply function, but foreign variables and the domestic expected tax rate usually do not.

Workers set the nominal wage such as to achieve a target real wage. After substituting the optimal wage rule ($w_i = p_i^e$, see Appendix A), we find the following equations for supply per capita:

$$y_1 = -kt_1^e + (\pi_1 - \pi_1^e - t_1 + t_1^e) - (\pi_2 - \pi_2^e - t_2 + t_2^e) + \varepsilon_1, \quad (2a)$$

$$y_2 = -kt_2^e - (\pi_1 - \pi_1^e - t_1 + t_1^e) + (\pi_2 - \pi_2^e - t_2 + t_2^e) + \varepsilon_2, \quad (2b)$$

where π_i is the increase in the general price level, $i = 1, 2$.

In the absence of tax distortions and shocks, $y_i = 0$ in a rational-expectations equilibrium. Expected output is affected only by the expected domestic tax rate. The second and third terms of the supply function indicate that a money surprise ($\pi_i \neq \pi_i^e$) and a tax surprise ($t_i \neq t_i^e$) can be used by the authorities to induce a shift of economic activity from one country to the other. Note that total per capita worldwide output only depends on the average expected tax rate and shocks. The simplifying assumption that the world supply curve is vertical is made since, in this paper, I want to focus on shifts of economic activity, not on the possibility that policy surprises may be used to increase world output.

I allow not only for tax distortions, but also for non-tax distortions. The latter may be due to, for example, union control over the labour market or monopoly control over commodity markets. The first-best level of output (i.e. output with neither tax nor non-tax distortions) is denoted by y_i^* (> 0). Because the equilibrium level of output in the absence of tax distortions has been normalised to zero, y_i^* is also a measure for non-tax distortions.

This paper looks at supply shocks only. Supply shocks pose a bigger dilemma for central banks in terms of the trade-off between inflation and output than demand shocks. This means that supply shocks are the more interesting case. Moreover, Bayoumi and Eichengreen (1993) find empirically that international spillovers on the supply side are more important than demand spillovers.

2.2 Policymakers

Fiscal authorities set taxes and spending in order to minimise:

$$L_i^{FA} = \frac{1}{2}[\pi_i^2 + \gamma(y_i - y_i^*)^2 + \phi(g_i - g_i^*)^2], \qquad i = 1, 2, \tag{3}$$

which corresponds to the loss function of society. The preferred inflation rate is normalised to zero (i.e. $\pi_i^* = 0$, $i = 1, 2$), and the output target is equal to its first-best level y_i^*. The government spending target, g_i^*, can be interpreted as the optimal share of non-distortionary output to be spent on public goods if sufficient lump-sum taxes are available. The parameters γ and ϕ (>0) indicate the relative weight attached to the different policy goals by the government.

I will assume that ϕ and γ are equal across countries. However, the targets y_i^* and g_i^* may differ across countries.[2]

The government budget constraint is:[3]

$$g_i = t_i + \mu\pi_i, \quad i = 1, 2, \tag{4}$$

where μ (>0) represents the (constant) ratio of real money holdings as a share of the first-best level of output in equilibrium, i.e. in the absence of distortions and economic shocks.[4]

When adverse shocks occur, each government has an incentive to inflate away the domestic real wage and to cut taxes in order to import jobs and production from the foreign country (Martin, 1997). Cutting taxes and

[2] One could argue that a high level of g^* is typical for a continental-European government, which finds it important to provide an adequate level of public goods and services, whereas a low level of g^* would be typical for an Anglo-Saxon government, whose main goal would be to increase the economic growth potential by a policy of 'small government' and a low level of taxation, in order not to create too many distortions. Later on, I will allow for this possibility by distinguishing between g_E^* (for Europe) and g_S^* (for the United States). However, the focus here is not on the *level* of the government spending target, but on the relative *weights* attached to the spending and output targets, respectively.

[3] In this paper, the terms government and fiscal authorities are used interchangeably.

[4] The budget constraint is derived using the Fisher equation. It is assumed that real money demand does not depend on expected inflation. See Beetsma and Bovenberg (1999a) for a derivation of a more general version of this constraint.

creating inflation are beggar-thy-neighbour policies in this model, in the sense that they harm foreign output [see equations (2a)-(2b)].

Monetary policy is delegated to central banks. They are assumed to have direct and full control over the inflation rate (the inflation rate is their policy instrument). Their loss function is given by:

$$L_i^{CB} = \frac{1}{2}[\pi_i^2 + \beta(y_i - y_i^*)^2], \qquad i = 1, 2. \tag{5}$$

The parameter β (>0) represents the relative weight attached to both goals by the policy maker. The output targets of the central banks correspond to the output targets of their governments, but the relative weight β will generally differ from γ. I assume that β is equal for all central banks in this model.

Even in the absence of stochastic shocks, the central bank and the government are unable to attain all policy goals simultaneously, due to the presence of tax and non-tax distortions. Therefore, policymakers have an incentive to generate a policy surprise after private expectations are formed.

2.3 Framework for welfare evaluation

Making use of equation (1), the government budget constraint of the home country can be rewritten as follows:

$$\begin{aligned} y_1^* + g_1^* - \varepsilon_1 &= (y_1^* - y_1) + (g_1^* - g_1) + \mu\pi_1 + \\ &\quad + (\pi_1 - \pi_1^e) - (k-1)t_1^e - (\pi_2 - \pi_2^e) + (t_2 - t_2^e). \end{aligned} \tag{6}$$

The left hand side of equation (6) contains the exogenous distortions to the domestic economy. It consists of a deterministic component (the first two terms) and a stochastic component. The first term can be interpreted as a labour subsidy which would just offset the implicit tax on output created by non-tax distortions, the second term is the government spending target which needs to be financed by distortionary taxation. The third term on the left hand side is a stochastic supply shock which may hit the domestic economy.

The right hand side of equation (6) provides insight into the tradeoff to be made by domestic and foreign fiscal authorities. The first three terms correspond to the three components in the loss functions of the domestic fiscal authority. Deviations of output, government spending and inflation from their policy targets are costly in terms of welfare. The authorities use tax and inflation policies in order to attain the optimal distribution of the welfare losses over the target variables. The fourth term on the right hand side is an inflation surprise. An inflation surprise is a 'source of finance' in the sense that it helps to absorb a stochastic shock in an effort to meet the government policy objectives.

So far, the right hand side is identical to Beetsma and Bovenberg (1999b). The remaining terms are new. The fifth term on the right hand side is the expected tax level, multiplied by $(k-1)$. This term appears because output is more responsive to the expected tax rate (coefficient k) than to a tax surprise (coefficient 1). A positive expected tax rate has a downward impact on output. Conversely, an expected subsidy (a negative expected tax rate) would have a stimulative impact on output and contribute to meeting the objectives.

The final two terms represent policy moves by the foreign authorities in response to stochastic shocks. Such policies are intended to be stabilising for the foreign country, but they are beggar-thy-neighbour in the sense that they may lead to a shift of economic activity from the home country to the foreign country, which makes it more difficult for the domestic fiscal authorities to meet the policy objectives.

Before turning to solving the model, it is useful to summarise the timing of events and actions. First, private expectations are formed and wages are set. Secondly, workers are hired. Third, supply shocks occur. Fourth, monetary and fiscal policy decisions are made. All policy makers play Nash against each other. Finally, workers may be relocated among countries (but not hired or fired).

2.4 Solution of the model

Let the two 'countries' be the euro area and the United States. In this subsection, the ECB is the monetary authority and the Ecofin is the fiscal authority of the euro area (country 1). The Federal Reserve is the monetary authority and the Treasury is the fiscal authority of the US (country 2). Due to the symmetry of the model, it suffices to solve the model for euro area variables. In the remainder of this paper, the subscript E denotes the euro area and the subscript S denotes the United States.

All policy makers play Nash against each other. Substituting the supply curve (2a) and the government budget constraint (4) into the loss function of the Ecofin (3) and minimising with respect to the euro area tax rate (its policy instrument) gives the first-order condition for the Ecofin:

$$\phi(g_E - g_E^*) = \gamma(y_E - y_E^*). \tag{7}$$

This condition gives the optimal balance between spending stabilisation and output stabilisation for the Ecofin. It is optimal for the Ecofin to distribute distortions and shocks over the output gap and the *government spending gap* (defined as the difference between the actual and the desired level of government spending) in a ratio $\frac{\phi}{\gamma}$.

Substituting the euro area supply curve (2a) into the loss function of the ECB (5) and minimising with respect to euro area inflation, which is the ECB´s policy instrument, gives the first-order condition for the ECB:

$$\pi_E = -\beta(y_E - y_E^*). \tag{8}$$

This condition gives the optimal balance between inflation fighting and output stabilisation for the ECB. It is optimal for the ECB to distribute distortions and shocks over the *output gap* (defined as the difference between actual output and the output target) and inflation in a ratio $\frac{1}{\beta}$.

The deterministic and stochastic parts of the model can be solved separately. The expected values of all variables can be expressed as a function of the structural distortions. The deviation of the expected value of all variables can be expressed as a function of the stochastic shocks. The solution in terms of the determinants of welfare ($y_E^* - y_E$, $g_E^* - g_E$, $\mu\pi_E$) and the other variables in equation (6) is shown in Table 1. The next two subsections discuss the deterministic and stochastic components of the solution. It will turn out that the inability of policymakers to commit plays an important role in understanding the deterministic components ('structural distortions'), whereas the presence of international spillovers plays an important role in interpreting the stochastic components ('unanticipated shocks').

2.5 Distortions and commitment problems

The deterministic components of all variables in Table 1 are functions of the exogenous distortions g_E^* and y_E^*. The presence of structural distortions implies that policymakers are unable to attain all policy goals simultaneously. The higher the distortions, the more output and government spending will be below their policy targets and the higher inflation will be in equilibrium.

The impact of the distortions on the tax rate is more subtle. A high target for government spending g_E^* leads to a high expected tax rate. Intuitively, a high target share of government spending will have to be matched by high government revenues. By contrast, a high level of non-tax distortions y_E^* leads to a low expected tax rate. Intuitively, non-tax distortions will erode the tax base (output), increasing the relative attractiveness of seigniorage over output tax as an instrument to generate government revenues. Moreover, an increase in taxes is relatively costly in terms of welfare if the level of non-tax distortions is high, because it widens further the deviation of output from its target.

Table 1 Solution to the two-country game

variable	deterministic component	stochastic component
$y_E^* - y_E$	$\frac{\phi}{\phi+k(\phi\mu\beta+\gamma)}[g_E^* + y_E^* + (k-1)g_E^*]$	$-(A_1\varepsilon_E + A_2\varepsilon_S)$
$g_E^* - g_E$	$\frac{k\gamma}{\phi+k(\phi\mu\beta+\gamma)}[g_E^* + y_E^* - (\frac{k-1}{k})y_E^*]$	$-\frac{\gamma}{\phi}(A_1\varepsilon_E + A_2\varepsilon_S)$
$\mu\pi_E$	$\frac{k\phi\mu\beta}{\phi+k(\phi\mu\beta+\gamma)}[g_E^* + y_E^* - (\frac{k-1}{k})y_E^*]$	$-\mu\beta(A_1\varepsilon_E + A_2\varepsilon_S)$
$-(k-1)t_E^e$	$\frac{k\phi\mu\beta+k\gamma}{\phi+k(\phi\mu\beta+\gamma)}(\frac{k-1}{k})y_E^* +$ $-\frac{\phi}{\phi+k(\phi\mu\beta+\gamma)}(k-1)g_E^*$	0
$\pi_E - \pi_E^e$	0	$-\beta(A_1\varepsilon_E + A_2\varepsilon_S)$
$-(\pi_S - \pi_S^e)$	0	$\beta(A_2\varepsilon_E + A_1\varepsilon_S)$
$t_S - t_S^e$	0	$\frac{\phi\mu\beta+\gamma}{\phi}(A_2\varepsilon_E + A_1\varepsilon_S)$

where

$$A_1 = \frac{\phi + H}{\phi + 2H}; \qquad A_2 = \frac{H}{\phi + 2H}; \qquad H = \phi\beta(1+\mu) + \gamma.$$

I will, realistically, assume that policymakers are unable to commit. Nominal wages are influenced by the expected inflation rate, but cannot adjust to an inflation surprise. This causes the familiar time-inconsistency of monetary policy. The absence of monetary policy commitment gives rise to an upward inflation bias. Fiscal policy is subject to a time-inconsistency problem as well. Stimulating output requires reducing the tax rate, whereas an increase in government spending calls for raising the tax rate. Output is less responsive to a tax surprise than to the expected tax rate.[5] This

[5] Recall that the total amount of labour is fixed when workers are hired. Therefore, firms lose a degree of freedom between the moment when they form expectations about the tax rate and the moment when the tax surprise materialises.

means that the optimal tradeoff shifts in favour of a higher tax rate after the private sector has formed expectations about tax rates. Firms are aware of the fact that the fiscal authorities have an incentive to announce a lower tax rate than they will choose ex-post. Therefore, the absence of fiscal commitment gives rise to an upward tax bias. Intuitively, the monetary time-inconsistency problem is caused by the short-run rigidity of nominal wages, whereas the fiscal time-inconsistency problem is caused by short-run constraints on output (although the model does not formally distinguish between the short run and the long run).

Time-inconsistencies arise both via the wage rate and via output in my model. By contrast, in Alesina and Tabellini (1987) and Bryson, Jensen, Van Hoose (1993), time-inconsistencies arise only via the wage rate. In Alesina and Tabellini (1987), tax rates enter the supply curve, but fiscal policy is not subject to time-inconsistencies.[6] In Bryson, Jensen, Van Hoose (1993), fiscal policy is subject to time-inconsistencies. The contracted nominal wage rate depends negatively on the expected tax rate. In their model, as in mine, expected and unexpected tax cuts stimulate output. In their model, output is more sensitive to a surprise tax cut than to an expected tax cut, which gives rise to a downward tax bias. In my model, by contrast, output is more sensitive to an announced tax cut than to a surprise tax cut. Fiscal authorities compete for multinational firms by offering an attractive tax environment. However, sovereign countries cannot make a credible commitment that the tax treatment will not be changed after multinational firms have made substantial investments in the country. This gives rise to an upward tax bias.

If output were equally responsive to the expected tax rate and a tax surprise ($k = 1$), the determinants of welfare would be functions of $g_E^* + y_E^*$. Instead, output is more responsive to the expected tax rate than to a tax surprise ($k > 1$). Intuitively, firms are quite sensitive to the tax environment before they have made substantial investments. This 'tax announcement effect' raises the welfare cost of the desired level of government spending (g_E^*, which increases the expected tax rate), whereas it reduces the welfare cost of non-tax distortions (y_E^*, which reduce the expected tax rate).

The deterministic component of the variables in Table 1 add up to $g_E^* + y_E^*$, as required by equation (6). This indicates that the upward tax

[6] In Alesina and Tabellini (1987), the wage rate as set by the labour unions depends on expected inflation, but not on the expected output tax rate. There is also no impact of taxes on wages via the inflation rate, as central banks directly control the inflation rate. Therefore, the impact of taxes on output is the same before and after nominal wages are determined. Thus, fiscal policy is not subject to time-inconsistencies.

bias which results from the fiscal commitment problem is costly in terms of welfare: a higher expected tax rate implies that a larger share of the distortions will fall on the three determinants of welfare (output gap, spending gap and inflation).

The distribution of the total distortion $g_E^* + y_E^*$ over the three determinants of welfare and the expected tax rate depends on the preferences of the government (ϕ, γ) and the central bank (β) and on the importance of seigniorage to the government budget (μ). First, a fiscal authority which is inclined to close the output gap rather than the spending gap ($\frac{\gamma}{\phi}$ high) will endeavour to achieve this by lowering the tax rate. The balanced budget requirement forces the government to curb spending. The lower tax rate implies that there is less need for the central bank to allow a rise in inflation in order to stimulate output. Second, a less conservative central bank (β high) is more inclined to close the output gap. It will achieve this by letting inflation increase. The higher seigniorage income allows the fiscal authority to set a lower tax rate and simultaneously increase the level of government spending. Thrid, a large real money stock (μ high) means that there is a large inflation tax base, making it more attractive to create inflation in order to generate government revenues. On the other hand, a lower inflation rate would be needed to generate the same level of government revenues. It turns out that the latter dominates the former: the equilibrium inflation rate will be lower. Nevertheless, seigniorage makes a more significant contribution to government revenue. This makes it easier for the fiscal authority to achieve its policy targets. The fiscal authority is able to lower its tax rate and simultaneously increase government spending. The lower tax rate induces a higher level of output, which implies that there is less of a need for the central bank to raise inflation in order to protect employment.

2.6 Shocks and international spillovers

The stochastic components of all euro area variables in Table 1 are functions of the composite shock $A_1\varepsilon_E + A_2\varepsilon_S$. The euro area economy is affected by both domestic and foreign shocks, although euro area variables are more sensitive to euro area shocks than to US shocks.

Note that euro area variables are affected by unanticipated US shocks ε_S, but not by US distortions g_S^* and y_S^*. This feature of the model fits reality, in the sense that policymakers tend to be more concerned about possible international spillovers from an unexpected adverse foreign shock, than about known structural distortions in a foreign country.

The stochastic components of the variables in Table 1 add up to $-\varepsilon_E$, as required by equation (6). Inflation surprises cannot contribute to the financing of the deterministic component, because wage-setters have rational expectations and thus anticipate the effect of the deterministic distortions on inflation when setting wages. However, shocks occur only after wage contracts have been signed. Therefore, inflation surprises can contribute to the 'financing' of stochastic shocks.

As already mentioned in the discussion of equation (6), foreign policy responses to home country shocks enhance the need for the home country authorities to respond and causes them to overrespond. The fact that all policymakers play Nash means that they cannot collaborate in order to achieve a better outcome. International policy spillovers increase the variance of macroeconomic variables. This increase in the 'financing requirement' may more than offset the contribution of a domestic inflation surprise to financing the stochastic component.

Equations (2a)-(2b) imply that total worldwide activity only depends on the average expected tax rates and shocks. Therefore, surprise policy moves cannot alleviate the impact of a shock on world output. However, foreign policy responses to shocks are a source of uncertainty to domestic policy makers. This can be seen as follows. If the stochastic components of the three determinants of welfare for the euro area are added to those for the US (not reported in Table 1) the result is

$$-(1+\beta+\frac{\gamma}{\phi})(\varepsilon_E+\varepsilon_S). \tag{10}$$

If central banks would exclusively focus on maintaining price stability and fiscal authorities would only care for attaining the government spending target, the right-hand side of equation (10) would be just $-(\varepsilon_E+\varepsilon_S)$, i.e. minus the sum of the stochastic disturbances. Beggar-thy-neighbour policy moves do not affect the variance of world output, whereas they increase the variance of inflation and government spending. In the right-hand side of equation (10), the term 1 (multiplied by $\varepsilon_E+\varepsilon_S$) reflects the size of the exogenous stochastic supply shock. The terms β and $\frac{\gamma}{\phi}$ reflect beggar-thy-neighbour aspects of monetary and fiscal policy, respectively.

2.7 Welfare

The euro area's welfare loss follows upon substitution of the solutions for $y_E^*-y_E$, $g_E^*-g_E$ and $\mu\pi_E$ into equation (3). The distortions g_E^* and y_E^* are non-stochastic. The stochastic shocks ε_E and ε_S have zero expected value and are uncorrelated with each other. Therefore, the equilibrium expected welfare loss of the euro area is:

$$E(L_E) = \frac{\phi\beta^2 + \phi\gamma + \gamma^2}{2\phi}[\frac{\phi^2}{(\phi + k\phi\mu\beta + k\gamma)^2}(kg_E^* + y_E^*)^2 + \frac{(\phi + H)^2 + H^2}{(\phi + 2H)^2}\sigma^2]. \tag{11}$$

Society's welfare is thus composed of a term arising from deterministic distortions and a term associated with stochastic (supply) shocks. Examples of these structural distortions are union control over the labour market and monopoly control over commodity markets. Examples of unanticipated shocks are oil price shocks and a credit crunch. Let us look at the implications of the fiscal commitment problem and international spillovers for welfare.

First, the inability of fiscal policymakers to commit leads to an upward bias in the expected tax rate. Since output is more responsive to the expected tax rate than to a tax surprise, it follows that the inability of fiscal policymakers to commit increases the welfare cost of structural distortions.[7,8] The implication is that models that neglect the fiscal commitment problem will tend to underestimate the welfare cost of structural distortions.

Second, recall that the foreign policy response to unanticipated shocks leads to international spillovers. The foreign policy responses are a source of uncertainty to domestic policy makers (they result in a higher variability of output, inflation and government spending) and make unanticipated shocks more costly in terms of welfare. In the absence of international cooperation, policymakers tend to overrespond. This stresses the importance of international policy coordination, in particular in the aftermath of unanticipated shocks.

In the current model, it is ambiguous whether financing the deterministic component is more or less costly in terms of welfare than financing the stochastic component. The contribution of inflation surprises to financing the stochastic component may be more than offset by the welfare-reducing impact of foreign monetary and fiscal policy responses to shocks. Beetsma and Bovenberg (1999b) show that in the context of their model, it is less

[7] This is also true for the upward bias in the inflation rate, which follows from the inability of monetary policymakers to commit. Since the monetary commitment problem is studied by many others, it does not require much attention here.

[8] Intuitively, firms are better able to avoid structural distortions than stochastic shocks, since they observe distortions before making investment decisions, whereas they observe shocks after making investment decisions. A firm's decision not to invest in a country results in a lower level of output and is thus costly in terms of welfare for the country involved. Thus, because firms are better able to avoid structural distortions than stochastic shocks, the structural distortions are relatively costly to countries.

costly to finance stochastic shocks than deterministic distortions, as inflation surprises can contribute to financing the stochastic component and not to financing the deterministic component. Thus, the assertion by Beetsma and Bovenberg that it is less costly to finance stochastic shocks does not necessarily hold here.

3 Centralisation of monetary policy in Europe: A three-country model

In this paragraph, the model will be extended to a three-country version, in order to analyse the impact of the centralisation of monetary policy in Europe. Under floating rates, all three central banks and all three fiscal authorities play Nash. Under EMU, both central banks in Europe act as one decision maker (ECB), which again plays Nash against the Federal Reserve and the ministries of finance of the three countries.

3.1 Floating rates

3.1.1 Model specification

Germany (subscript G) and France (subscript F) are of equal size. The United States (subscript S) is twice as large as each of the European countries individually. Supply per capita is (see Appendix A):[9]

$$y_G = -kt_G^e + 2(\pi_G^d - t_G^d) - \left(\pi_F^d - t_F^d\right) - \left(\pi_S^d - t_S^d\right) + \varepsilon_G, \quad (12a)$$

$$y_F = -kt_F^e - (\pi_G^d - t_G^d) + 2\left(\pi_F^d - t_F^d\right) - \left(\pi_S^d - t_S^d\right) + \varepsilon_F, \quad (12b)$$

$$y_S = -kt_S^e - \frac{1}{2}(\pi_G^d - t_G^d) - \frac{1}{2}\left(\pi_F^d - t_F^d\right) + \left(\pi_S^d - t_S^d\right) + \varepsilon_S, \quad (12c)$$

where x^d is the deviation of a variable x from its expected value. Note that common policies and common shocks in Germany and France would reduce the system (12a)-(12c) to the two-country supply functions (2a)-(2b).

[9] Applying the size argument consistently argues for making Germany more sensitive to US than to French real wage developments. However, the geographical proximity of Germany and France (which is strictly speaking not in my model) argues for mitigating these differences, if not reversing them. I choose equal weights for reasons of algebraic simplicity. This amounts to assuming that each of the European countries is influenced as much by real wage changes in the US as by real wage changes in the other European country.

The structural distortions in Germany and France are assumed to be equal. In both countries, the desired level of government spending is g_E^*, whereas non-tax distortions are equal to y_E^*. The structural distortions in Europe may differ from those in the United States (g_S^*, y_S^*).

As in the two-country version of the model, world supply is a function of the expected tax rates and stochastic shocks, but is unaffected by policy surprises:

$$\frac{y_G + y_F}{2} + y_S = -k(\frac{t_G^e + t_F^e}{2}) - kt_S^e + \frac{\varepsilon_G + \varepsilon_F}{2} + \varepsilon_S. \tag{13}$$

The loss functions and the government budget constraints are completely analogous to the two-country case.

3.1.2 Solution of the model under floating rates

The solution procedure is identical to the one followed for the two-country case. The first-order conditions for the central banks are:

$$\pi_i = -2\beta(y_i - y_E^*), \qquad i = G, F, \tag{14a}$$

$$\pi_S = -\beta(y_S - y_S^*). \tag{14b}$$

The Federal Reserve will tend to choose a higher output loss and lower inflation than the Bundesbank and the Banque de France, because the relative size of the US (twice as large as each of the euro area countries individually) makes the Fed less effective in shifting the burden of output adjustment to other countries.

Analogously, the first-order condition for the fiscal authorities are:

$$\phi(g_i - g_E^*) = 2\gamma(y_i - y_E^*), \qquad i = G, F, \tag{15a}$$

$$\phi(g_S - g_S^*) = \gamma(y_S - y_S^*). \tag{15b}$$

The US government will find it optimal to choose a higher output loss and a lower spending gap than the German and French governments. The relatively large size of the US makes its government less effective in shifting the burden of output adjustment to other countries.[10]

The full solution to the game is reported in appendix B (Table B1). Its form is essentially the same as for the two-country case. The derivation of the welfare results is postponed until the next subsection.

[10] Recall that the authorities are assumed to have equal preferences. Thus, the results reflect the differences in trade-off that are due to differences in country size, rather than different political preferences.

3.2 EMU

3.2.1 Model specification

Under EMU, monetary policy in Europe is centralised, but fiscal policy is determined at the national level. As central banks are assumed to control the inflation rate directly, the creation of the European Central Bank implies that the inflation rates for Germany and France must be equal: $\pi_G = \pi_F$. This common inflation rate will henceforth be denoted as π_E. Substituting the common inflation rate into equations (12a)-(12c) gives the supply curves for Germany, France and the United States under EMU

$$
\begin{aligned}
y_G &= -kt_G^e + 2(\pi_E^d - t_G^d) - \left(\pi_E^d - t_F^d\right) - \left(\pi_S^d - t_S^d\right) + \varepsilon_G, \quad (16a)\\
y_F &= -kt_F^e - (\pi_E^d - t_G^d) + 2\left(\pi_E^d - t_F^d\right) - \left(\pi_S^d - t_S^d\right) + \varepsilon_F, \quad (16b)\\
y_S &= -kt_S^e - \frac{1}{2}(\pi_E^d - t_G^d) - \frac{1}{2}\left(\pi_E^d - t_F^d\right) + \left(\pi_S^d - t_S^d\right) + \varepsilon_S. \quad (16c)
\end{aligned}
$$

Recall that Germany and France are assumed to be of equal size. Therefore, income per capita of the euro area is equal to the average of income per capita in the two euro area countries individually: $y_E = (y_G + y_F)/2$. Under EMU, the ECB minimises:[11]

$$L_E^{CB} = \frac{1}{2}[\pi_E^2 + \beta(y_E - y_E^*)^2]. \quad (17)$$

According to the EU Treaty, seigniorage is shared between the participating countries according to the capital key, which consists of population size and the size of the economy. Both variables have a weight of 50%. In this model, the implication is that seigniorage is shared equally between both countries. The German and French government budget constraints become:

$$g_i = t_i + \mu\pi_E, \qquad i = G, F. \quad (18)$$

Under EMU, the German and French fiscal authorities minimise:

$$L_i^{FA} = \frac{1}{2}[\pi_E^2 + \gamma(y_i - y_E^*)^2 + \phi(g_i - g_E^*)^2], \qquad i = G, F, \quad (19)$$

[11] I implicitly assume that the members of the ECB Governing Council, who determine euro area monetary policy, look at euro area variables only. Alternatively, each member of the Governing Council votes according to national preferences. In that case, the ECB's loss function would be an average of the loss functions of the individual governors. My choice does not affect the resulting policy rules. See Benassy-Quere et al. (1997, p. 164) for a proof.

3.2.2 Solution of the model under EMU

The first-order condition for the ECB is:

$$\pi_E = -\beta(y_E - y_E^*). \tag{20}$$

The centralisation of monetary policy in Europe is reflected in the first-order condition for the ECB. The ECB will tend to choose a higher output loss and lower inflation than the Bundesbank and the Banque de France. Under floating rates, the national central banks in Europe act unilaterally and do not internalise the response of their counterparts. After the start of EMU, full monetary policy coordination takes place by the Governing Council of the ECB, where the externalities involved in unduly fierce policy responses are internalised. Therefore, the ECB is less aggressive in its attempts to shift part of the burden of supply shocks abroad. It should be stressed that the ECB keeps inflation closer to zero, not because the ECB is more inflation averse, but because of the possibility of the participating central banks to commit against each other.

The first-order condition for the other authorities are identical to the conditions under floating rates. The full solution to the game under EMU is reported in Appendix B (Table B2).

3.2.3 Macroeconomic effects of EMU

The start of EMU (Europe moves from floating rates to EMU) has several consequences. Most importantly, intra-European spillovers in monetary policy are internalised. The ECB still has the incentive to conduct a beggar-thy-neighbour policy against the United States, but not anymore within Europe. This leads to a lower inflation bias.

The resulting lower level of seigniorage income makes it more difficult to attain the governments' policy targets for output and government spending. Another consequence of EMU is that seigniorage is shared between the euro area governments. The euro area fiscal authorities know that a tax cut will induce a tougher monetary policy (lower inflation), which partly offsets the impact of a tax cut on output and leads to lower seigniorage revenues as a side effect. Under EMU, the other euro area member state carries part of the seigniorage loss, which enhances the attractiveness of a tax cut. Both seigniorage-related effects are of second-order importance, given the limited significance of seigniorage as a source of government revenue in the euro area (as in the United States).

The ECB will be less responsive to German shocks than the Bundesbank used to be under floating rates. The intuition is that, first, the ECB is less effective in stabilising German output (monetary policy cannot be directed at country-specific circumstances), and secondly, German shocks are less important to the ECB than to the Bundesbank. Whether the ECB will be more or less responsive to *French* shocks than the Bundesbank, is ambiguous. For plausible parameter values ($\phi = 40$, $\gamma = 9$, $\beta = .1$ and $0 < \mu < 1$), the ECB will respond more actively to French shocks than the Bundesbank, as one would expect given that French output is not in the Bundesbank's loss function.[12] The ECB will be less responsive to US shocks than the Bundesbank. Intuitively, the ECB internalises the intra-European spillovers which used to exist when all euro area national central banks responded to US shocks individually.

3.2.4 Welfare impact of EMU

Under floating rates, the equilibrium expected welfare loss for Germany (or for France, after substituting subscripts F for G) is:

$$\begin{aligned} E(L_G) &= \frac{4\phi\beta^2 + \phi\gamma + 4\gamma^2}{2\phi}\{\frac{\phi^2}{(\phi + 2k\phi\mu\beta + 2k\gamma)^2}(kg_E^* + y_E^*)^2 + \\ &+[(\frac{\phi(\phi + 3H) + H(2\phi + 3H)}{(\phi + 3H)(\phi + 6H)})^2 + \\ &+(\frac{H(2\phi + 3H)}{(\phi + 3H)(\phi + 6H)})^2 + (\frac{\phi}{\phi + 3H})^2]\sigma^2\}, \end{aligned} \tag{21}$$

and the equilibrium expected welfare loss for the US is:

$$\begin{aligned} E(L_S) &= \frac{\phi\beta^2 + \phi\gamma + \gamma^2}{2\phi}[\frac{\phi^2}{(\phi + k\phi\mu\beta + k\gamma)^2}(kg_S^* + y_S^*)^2 + \\ &+(\frac{(\phi + 2H)^2 + (2H)^2}{(\phi + 3H)^2})\sigma^2]. \end{aligned} \tag{22}$$

Under EMU, the equilibrium expected welfare loss for Germany (or, equivalently, for France) is:

$$\begin{aligned} E(L_G) &= \frac{\phi\beta^2 + \phi\gamma + 4\gamma^2}{2\phi}\{\frac{\phi^2}{(\phi + k\phi\mu\beta + 2k\gamma)^2}(kg_E^* + y_E^*)^2 + \\ &+[(\frac{\phi^2 + 2\phi H + 2H^2}{(\phi + \gamma + 2H)^2}) + \frac{\phi\gamma(\phi + 4\gamma)}{(\phi + 6\gamma)^2}]\sigma^2\}, \end{aligned} \tag{23}$$

[12] These parameter values are put forward as plausible by Eichengreen and Ghironi (1997).

and the equilibrium expected welfare loss for the US is:

$$E(L_S) = \frac{\phi\beta^2+\phi\gamma+\gamma^2}{2\phi}\{\frac{\phi^2}{(\phi+k\phi\mu\beta+k\gamma)^2}(kg_S^*+y_S^*)^2+ \\ +\frac{(\phi+\gamma)^2+2(\phi+\gamma+H)^2}{2(\phi+\gamma+2H)^2}\sigma^2\}. \quad (24)$$

When comparing the expressions for welfare under floating rates and EMU, it is assumed that the real money stock is relatively small ($\mu \rightarrow 0$), which implies that seigniorage is relatively unimportant to the government budget. For the euro area and the United States, this seems realistic.

First, the impact of EMU on welfare of a euro area member state (Germany) is considered. The part of the German loss function associated with deterministic distortions is smaller under EMU than under floating rates. The reason for the welfare improvement is that intra-European monetary externalities are internalised as a result of EMU, which means that the incentive for central banks to create surprise inflation has declined. Thus, the inflation bias declines.

The impact of EMU on the part of the German loss function associated with stochastic distortions is ambiguous. On the one hand, the euro area authorities lose a policy instrument, as country-specific shocks can no longer be addressed by monetary policy. This makes it more difficult for the fiscal authorities in each of the participating member states to attain their policy goals, which is welfare-reducing. On the other hand, the incentives to run beggar-thy-neighbour policies are partly internalised as a result of EMU, which reduces the tendency of euro area monetary authorities to overrespond to shocks. The net welfare consequences of EMU for Europe depend on the relative importance of low inflation versus the other government policy goals (stable output and spending) and on the variance of shocks. The positive welfare impact of improved policy incentives may or may not be dominated by the negative welfare impact of the loss of a policy instrument.

Next, look at US welfare. The part of the US welfare function associated with deterministic distortions does not change as a result of EMU. As the US does not participate in EMU, the credibility of the US authorities (reflected in the US inflation bias) is unaffected by the changed institutional setting in Europe. The part of the US welfare function associated with stochastic shocks is unambiguously smaller under EMU than under floating rates. The intuition is that the US benefits from the fact that, compared to the euro area national central banks under floating rates, the ECB is less engaged into shifting abroad the burden of adjustment to shocks. Thus, it follows that EMU is unambiguously welfare-improving for the United States.[13]

4 Conclusion

In this paper, I have looked at the possible macroeconomic and welfare consequences of EMU. The model in this paper stresses the importance of cross-border spillovers and of the internalisation of externalities that occurs as a result of EMU. It extends a model by Martin (1997) to take into account the interaction between monetary and fiscal policy and the existence of a third country which does not participate in monetary union, but is large enough to have a substantial influence on the economy of the euro area.

Structural distortions and uanticipated shocks generate a ´financing requirement' in the sense that adjustment of macroeconomic variables needs to take place. As pointed out by Beetsma and Bovenberg (1999b), an inflation surprise can be used to shift part of the burden of an unanticipated shock to private sector agents, but cannot be used to finance deterministic distortions. This makes it less costly in terms of welfare to finance unanticipated shocks. My paper adds two new insights in this respect.

First, international spillovers increase the welfare costs of unanticipated shocks. The foreign policy responses to shocks, while intended to be stabilising for the foreign country, may be beggar-thy-neighbour in the sense that they lead to a shift of economic activity from the home country to the foreign country. This may aggravate the welfare consequences of a negative shock. The foreign policy responses to an adverse supply shock may more than offset the contribution of a domestic inflation surprise to financing the stochastic component. Thus, the assertion by Beetsma and Bovenberg that it is less costly to finance stochastic shocks does not necessarily hold here.

Secondly, the lack of fiscal commitment increases the welfare cost of structural distortions. While not eliminating the above ambiguity, this provides support to Beetsma and Bovenberg's assertion that structural distortions are more costly in welfare terms than unanticipated shocks. Intuitively, output is more responsive to distortions than to shocks. The reason is that firms know structural distortions before making their investment decisions, whereas they are partly locked in when unforeseen shocks occur. The lack of commitment creates an upward bias in the expected tax rate. The fact that firms are more responsive to the expected tax rate than to a tax surprise

[13] The ambiguous welfare result of monetary unification for the monetary union itself is in line with the theory on optimal currency areas. However, I am not aware of any articles that look at the welfare implications of a monetary union for third countries.

implies that the inability of fiscal policymakers increases the welfare cost of structural distortions. The implication is that neglecting the fiscal commitment problem results in underestimating the welfare cost of structural distortions.

The start of EMU has several consequences. First, and most importantly, intra-European spillovers in monetary policy are internalised. Under floating rates the national central banks in Europe endeavour to achieve their output target by causing beggar-thy-neighbour surprise inflation. Under EMU, part of this incentive is internalised: the ECB still has the incentive to conduct a beggar-thy-neighbour policy against the United States, but not anymore within Europe. This leads to a lower inflation bias. A second consequence of EMU is that seigniorage is shared between the national governments in Europe. The sharing of seigniorage means that euro area member states share some of the cost of a tougher monetary policy (lower seigniorage), which makes it less costly to cut taxes for an individual member state. However, since seigniorage is relatively unimportant, this effect is only small.

The ECB will be less responsive to German shocks than the Bundesbank used to be under floating rates, because the ECB is less effective in stabilising German output and because German shocks are less important to the ECB than to the Bundesbank. Whether the ECB will be more or less responsive to shocks in other euro area countries than the Bundesbank, is ambiguous. The ECB will be less responsive to US shocks than the Bundesbank, as the ECB internalises the intra-European spillovers that occur when all euro area national central banks respond to US shocks individually.

The impact of EMU on welfare in each of the euro area member states is ambiguous. On the one hand, the credibility problem of the national central banks is Europe is alleviated, since their incentive to create surprise inflation has declined. The resulting lower inflation bias is welfare-increasing. On the other hand, the euro area authorities lose a policy instrument, which makes it more difficult for the euro area fiscal authorities to attain their policy goals, which is welfare-reducing. Thus, in general, the welfare consequences of EMU for Europe are ambiguous, as the impact of the loss of a policy instrument may or may not be dominated by improved policy incentives.

EMU is unambiguously welfare-improving for the United States, as the credibility of the US authorities (reflected in the US inflation bias) is unaffected by the changed institutional setting in Europe, whereas the US suffers less from European beggar-thy-neighbour policies under EMU than under floating rates.

Appendices

A Derivation of supply functions

A.1 Output in N identical countries

The world consists of N identical countries of size 1. Capital is assumed to be fixed. Therefore, output in each economy is a function of labour input only: $Y_i = L_i^{\eta} e^{\xi_i}$, $i = 1, ..., N$, where Y_i is real output, L_i is labour input and ξ_i is a normally distributed, idiosyncratic shock with finite variance and expected value zero that hits country i (i.e. $E\xi_i = 0$, $Var(\xi_i) = (\sigma^*)^2$, $i = 1, ..., N$). The constant η satisfies $0 < \eta < 1$, implying a decreasing marginal productivity of labour. Firms are perfectly competitive. The representative firm is a multinational company with production sites in all countries.

The course of events is as follows. First, nominal wages are set by trade unions. Second, the firm contracts the desired number of workers. Third, random shocks occur. Fourth, monetary and fiscal policies are set. Fifth, workers can be relocated between countries in reaction to (monetary and fiscal) policy surprises and random economic shocks.

The model is solved via backward induction:

Step 5 (final step): The firm can relocate workers. However, workers cannot be laid off, nor can more workers be hired at this stage.[14] The representative firm maximises profits under the constraint that the size of the total workforce is pre-determined.

$$\begin{aligned} Max \ \prod &= (1-t_i)P_iY_i - W_iL_i + \\ &\quad + \sum_{j\neq i} X_{ij}[(1-t_j)P_jY_j - W_jL_j], \qquad \text{(A1)} \\ s.t. \ \sum_j L_j &= L^*, \end{aligned}$$

where X_{ij} is the price of the currency of country j in terms of the currency of country i. Using the assumption that purchasing power parity holds ($X_{ij}P_j = P_i$), deriving first-order conditions and re-arranging gives the following $N-1$ equations:

$$(1-t_i)\frac{\partial Y_i}{\partial L_i} - \frac{W_i}{P_i} = (1-t_j)\frac{\partial Y_j}{\partial L_j} - \frac{W_j}{P_j}, \qquad \forall j \neq i. \qquad \text{(A2)}$$

[14] This particular set-up helps to highlight the cross-border impact of government policies. Intuitively, countries compete for being a favourable production site.

Economic shocks and policy surprises may imply that the firm would like to hire or lay off workers. Since contracts have been signed before, it cannot do so. However, the possibility to relocate ensures that the given amount of workers will be optimally used. Equation (A2) states that workers will be relocated so as to equalise the difference between the (after tax) marginal product of labour and the real wage between countries. Using linear approximation and assuming that the tax rate and shocks are small, this can be rewritten as:

$$\frac{(1-t_i)\eta L_i^{\eta-1} e^{\xi_i}}{(1-t_j)\eta L_j^{\eta-1} e^{\xi_j}} - 1 = \frac{W_i/P_i}{W_j/P_j} - 1, \qquad \forall j \neq i. \tag{A3}$$

Eliminate corresponding terms, take logs and add all $N-1$ equations. Use equation (A9) below and the fact that the total number of employees is predetermined. Approximate $\log(1-t_i)$ by $-t_i$. The production function in terms of logs is: $y_i = \eta l_i + \xi_i$. Choose $\eta = \frac{N}{2N-1}$. Normalise y_i by subtracting the constant term $\frac{N}{N-1}\log(\frac{N}{2N-1})$. Then:

$$\begin{aligned} y_i &= -(\frac{N}{N-1})t_i^e - (w_i - p_i + t_i - t_i^e) + \\ &\quad + \frac{1}{N-1}\sum_{j\neq i}(w_j - p_j + t_j - t_j^e) + \varepsilon_i, \qquad \forall i, \end{aligned} \tag{A4}$$

where ε_i is a random shock with expectation zero and finite variance.
Step 4: Monetary and fiscal policies are set. See the main text (Section 2).
Step 3: Shocks occur. No optimisation takes place in this step.
Step 2: The representative firm hires the number of workers which will maximise expected total firm profits (expressed in the currency of country i):

$$Max_{\{L_1^*,\ldots,L_N^*\}} \; E\prod = E\{(1-t_i)P_iY_i - W_iL_i^* + \sum_{j\neq i} X_{ij}[(1-t_j)P_jY_j - W_jL_j^*]\}. \tag{A5}$$

At this stage, there is no constraint on labour. Shocks ξ_i are uncorrelated. Therefore, maximising expected worldwide profits is equivalent to maximising expected profits in each country separately. The firm´s expectations are formed and the L_i^* are chosen *before* shocks (ξ_i) and government policies (P_i, t_i) materialise. Since W_i is pre-determined and L_i^* is the representative firm´s choice variable, both variables are non-stochastic to the firm. Thus, (A5) can be rewritten as

$$Max_{\{L_i^*\}} \; E\prod = (L_i^*)^\eta E[(1-t_i)P_ie^{\xi_i}] - W_iL_i^*, \qquad i = 1, ..., N. \tag{A6}$$

The first-order condition for the maximisation of profits in country i is:

$$\eta(L_i^*)^{\eta-1}E\{(1-t_i)P_i e^{\xi_i}\} = W_i. \tag{A7}$$

Take logs and note that, for small shocks, $\log E\{..\} \approx E\log\{..\}$. Approximate $\log(1-t_i)$ by $-t_i$ and rearrange:

$$\log\eta + (\eta-1)l_i^* - t_i^e = w_i - p_i^e, \qquad i = 1,...,N. \tag{A8}$$

Equation (A8) is the familiar condition that the (expected) after tax marginal product of labour must be equal to the (expected) real wage. Optimal wage setting implies that the right hand side is equal to zero (see below). Therefore, equation (A8) simplifies to:

$$l_i^* = (\frac{1}{1-\eta})(-t_i^e + \log\eta), \tag{A9}$$

where l_i^* denotes the optimal amount of labour to be initially hired in country i.

Step 1: Workers choose the nominal wage. They minimise the expected square deviation of the real wage from the wage target (which is equal to zero for simplicity), which (after taking logs) yields the optimal wage rule $w_i = p_i^e$, $i = 1,...,N$. This completes the solution of the model via backward induction. The solution for output in N identical countries of size 1 is given in equation (A4).

A.2 Output per capita in three countries of unequal size

Here, the formulas for output per capita are derived for a world consisting of three countries of unequal size. Specifically, one country ('United States') is assumed to be twice as large as the other two countries ('Germany' and 'France') individually. The incorporation of the relative country size follows Martin (1997). Define a partition of the world in three super regions, comprising n_1, n_2, n_3 regions, respectively ($n_1 + n_2 + n_3 = N$). Shocks η_i have expected value zero and variance $\sigma^2, i = 1,...,N$. Assume that shocks within each super region are perfectly correlated, whereas shocks in different super regions are uncorrelated. Define $\varepsilon_k = \frac{1}{n_k}\sum_{i\in n_k}\eta_i, k = 1,2,3$. Then per capita supply in each super region is given by

$$
\begin{aligned}
y_1 &= \frac{1}{n_1}\sum_{i\in n_1}[-(\frac{N}{N-1})t_i^e - (w_i - p_i + t_i - t_i^e) + \\
&\quad + \frac{1}{N-1}\sum_{j\neq i}(w_j - p_j + t_i - t_i^e) + \eta_i] \\
&= \frac{1}{n_1}\sum_{i\in n_1}[-(\frac{N}{N-1})t_1^e - (w_1 - p_1 + t_1 - t_1^e) + \\
&\quad + \frac{1}{N-1}[(n_1-1)(w_1 - p_1 + t_1 - t_1^e) + n_2(w_2 - p_2 + t_2 - t_2^e) + \\
&\quad + n_3(w_3 - p_3 + t_3 - t_3^e)] + \eta_1] = \\
&\qquad = -(\frac{N}{N-1})t_1^e - (\frac{N-n_1}{N-1})(w_1 - p_1 + t_1 - t_1^e) + \\
&\qquad\quad + \frac{n_2}{N-1}(w_2 - p_2 + t_2 - t_2^e) + \\
&\qquad\quad + \frac{n_3}{N-1}(w_3 - p_3 + t_3 - t_3^e) + \varepsilon_1. \qquad \text{(A10)}
\end{aligned}
$$

The expressions for y_2 and y_3 can be found analogously. Normalise: $n_1 = n_2 = \frac{1}{2}; n_3 = 1$. Then:

$$
\begin{aligned}
y_1 &= -2t_1^e - \frac{3}{2}(w_1 - p_1 + t_1 - t_1^e) + \frac{1}{2}(w_2 - p_2 + t_2 - t_2^e) + \\
&\quad + (w_3 - p_3 + t_3 - t_3^e) + \varepsilon_1, \qquad \text{(A11)} \\
y_2 &= -2t_2^e + \frac{1}{2}(w_1 - p_1 + t_1 - t_1^e) - \frac{3}{2}(w_2 - p_2 + t_2 - t_2^e) + \\
&\quad + (w_3 - p_3 + t_3 - t_3^e) + \varepsilon_2, \qquad \text{(A12)} \\
y_3 &= -2t_3^e + \frac{1}{2}(w_1 - p_1 + t_1 - t_1^e) + \frac{1}{2}(w_2 - p_2 + t_2 - t_2^e) + \\
&\quad - (w_3 - p_3 + t_3 - t_3^e) + \varepsilon_3. \qquad \text{(A13)}
\end{aligned}
$$

I have adjusted the weights in the three-country model in the main text [equations (12a)-(12c)] in order to avoid non-integer coefficients and to capture the fact that Germany and France are geographically closer to each other than to the United States, while maintaining the other characteristics mentioned in the main text. In order to maintain the characteristic that output per capita is more responsive to the expected tax rate than to a tax surprise, the coefficient of the expected tax rate is set at k, with $k > 2$. The coefficient k is also used in the two-country version of the model (where it would have been sufficient to assume that $k > 1$). These adjustments do not qualitatively affect the conclusions of this article.

B Solution for three countries

The derivation of the solution for the three-country case is analogous to the two-country case.

The solution under floating rates and the solution under EMU are provided in Tables B1 and B2, respectively. The deterministic components of the variables in the tables are functions of the exogenous distortions g_E^* and y_E^*. The stochastic components of the German variables in the tables are functions of the composite shocks $\varepsilon_{G,\ float}^{comp.}$ and $\varepsilon_{G,\ EMU}^{comp.}$.

Table B1 Solution to the three-country game under floating rates

variable	deterministic component	stochastic component
$y_E^* - y_G$	$\frac{\phi}{\phi+2k(\phi\mu\beta+\gamma)}[g_E^* + y_E^* + (k-1)g_E^*]$	$-\varepsilon_{G,\ float}^{comp.}$
$g_E^* - g_G$	$\frac{2k\gamma}{\phi+2k(\phi\mu\beta+\gamma)}[g_E^* + y_E^* - (\frac{k-1}{k})y_E^*]$	$-\frac{2\gamma}{\phi}\varepsilon_{G,\ float}^{comp.}$
$\mu\pi_G$	$\frac{2k\phi\mu\beta}{\phi+2k(\phi\mu\beta+\gamma)}[g_E^* + y_E^* - (\frac{k-1}{k})y_E^*]$	$-2\mu\beta\varepsilon_{G,\ float}^{comp.}$
$-(k-1)t_G^e$	$\frac{2k\phi\mu\beta+2k\gamma}{\phi+2k(\phi\mu\beta+\gamma)}(\frac{k-1}{k})y_E^* +$ $-\frac{\phi}{\phi+2k(\phi\mu\beta+\gamma)}(k-1)g_E^*$	0
$2(\pi_G - \pi_G^e)$	0	$-4\beta\varepsilon_{G,\ float}^{comp.}$
$-(t_G - t_G^e)$	0	$-(2\mu\beta + \frac{2\gamma}{\phi})\varepsilon_{G,\ float}^{comp.}$
$-(\pi_F - \pi_F^e)$	0	$2\beta\varepsilon_{F,\ float}^{comp.}$
$t_F - t_F^e$	0	$(2\mu\beta + \frac{2\gamma}{\phi})\varepsilon_{F,\ float}^{comp.}$
$-(\pi_S - \pi_S^e)$	0	$\beta\varepsilon_{S,\ float}^{comp.}$
$t_S - t_S^e$	0	$(\mu\beta + \frac{\gamma}{\phi})\varepsilon_{S,\ float}^{comp.}$

where

$$\begin{aligned}
\varepsilon_{G,\ float}^{comp.} &= \frac{\phi}{\phi+6H}\varepsilon_G + \frac{H}{\phi+3H}[\frac{2\phi+3H}{\phi+6H}(\varepsilon_G+\varepsilon_F)+\varepsilon_S], \\
\varepsilon_{F,\ float}^{comp.} &= \frac{\phi}{\phi+6H}\varepsilon_F + \frac{H}{\phi+3H}[\frac{2\phi+3H}{\phi+6H}(\varepsilon_G+\varepsilon_F)+\varepsilon_S], \\
\varepsilon_{S,\ float}^{comp.} &= \frac{H}{\phi+3H}(\varepsilon_G+\varepsilon_F) + \frac{\phi+2H}{\phi+3H}\varepsilon_S,
\end{aligned}$$

with H as defined before.

Table B2 Solution to the three-country game under EMU

variable	deterministic component	stochastic component
$y^*_E - y_G$	$\frac{\phi}{\phi+k(\phi\mu\beta+2\gamma)}[g^*_E + y^*_E + (k-1)g^*_E]$	$-\varepsilon^{comp.}_{G,\ EMU}$
$g^*_E - g_G$	$\frac{2k\gamma}{\phi+k(\phi\mu\beta+2\gamma)}[g^*_E + y^*_E - (\frac{k-1}{k})y^*_E]$	$-\frac{2\gamma}{\phi}\varepsilon^{comp.}_{G,\ EMU}$
$\mu\pi_E$	$\frac{k\phi\mu\beta}{\phi+k(\phi\mu\beta+2\gamma)}[g^*_E + y^*_E - (\frac{k-1}{k})y^*_E]$	$-\mu\beta\varepsilon^{comp.}_{E,\ EMU}$
$-(k-1)t^e_G$	$\frac{k\phi\mu\beta+2k\gamma}{\phi+k(\phi\mu\beta+2\gamma)}(\frac{k-1}{k})y^*_E +$ $-\frac{\phi}{\phi+k(\phi\mu\beta+2\gamma)}(k-1)g^*_E$	0
$\pi_E - \pi^e_E$	0	$-\beta\varepsilon^{comp.}_{E,\ EMU}$
$-(t_G - t^e_G)$	0	$-(\mu\beta + \frac{2\gamma}{\phi})\varepsilon^{comp.}_{G,\ EMU}$
$t_F - t^e_F$	0	$(\mu\beta + \frac{2\gamma}{\phi})\varepsilon^{comp.}_{F,\ EMU}$
$-(\pi_S - \pi^e_S)$	0	$\beta\varepsilon^{comp.}_{S,\ EMU}$
$t_S - t^e_S$	0	$(\mu\beta + \frac{\gamma}{\phi})\varepsilon^{comp.}_{S,\ EMU}$

where

$$\begin{aligned}
\varepsilon^{comp.}_{G,\ EMU} &= \frac{\phi+H}{\phi+\gamma+2H}\varepsilon_E + \frac{\phi}{\phi+6\gamma}\varepsilon_{G-E} + \frac{H}{\phi+\gamma+2H}\varepsilon_S; \\
\varepsilon^{comp.}_{F,\ EMU} &= \frac{\phi+H}{\phi+\gamma+2H}\varepsilon_E + \frac{\phi}{\phi+6\gamma}\varepsilon_{F-E} + \frac{H}{\phi+\gamma+2H}\varepsilon_S; \\
\varepsilon^{comp.}_{S,\ EMU} &= \frac{\gamma+H}{\phi+\gamma+2H}\varepsilon_E + \frac{\phi+\gamma+H}{\phi+\gamma+2H}\varepsilon_S,
\end{aligned}$$

with $\varepsilon_E = \frac{1}{2}(\varepsilon_G + \varepsilon_F)$, $\varepsilon_{G-E} = \varepsilon_G - \varepsilon_E$, $\varepsilon_{F-E} = \varepsilon_F - \varepsilon_E$, $\varepsilon^{comp.}_{E,\ EMU} = \frac{1}{2}(\varepsilon^{comp.}_{G,\ EMU} + \varepsilon^{comp.}_{F,\ EMU})$ and H as defined before.

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