European Integration, Monetary Policy and Exchange Rate Behaviour
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Chapter 3

The Welfare Implications of EMU: The Role of Credibility Problems and International Spillovers

Summary

This chapter analyses the welfare implications of EMU. It shows that the welfare impact of EMU for Europe is ambiguous, but that EMU is welfare-improving for the US. It also shows that the ECB will be less responsive to German shocks and less responsive to shocks outside the euro area than the Bundesbank used to be. The analyses is conducted by developing a monetary-fiscal game which stresses the importance of international spillovers and introduces a monetary and fiscal credibility problem.

3.1 Introduction

Economic and monetary union (EMU) in Europe has raised several concerns, both inside and outside the euro area. One concern, which has been voiced in the United States in particular, that ‘the rest of the world’ will suffer as a result of EMU, either because Europe will become more inward-looking and more closed to the outside world (‘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 potential 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.
Chapter 3. The Welfare Implications of EMU

Whether Europe will become more inward-looking and/or more self-confident is outside the scope of this chapter. Rather, it 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 article specifies a policy game involving central banks and fiscal authorities. The policy game takes place in a world of three countries (Germany, France, United States). Monetary policy is determined by independent central banks. Initially, both monetary and fiscal policy are determined at the national level in each country. Then Germany and France 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 (United States) 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 monetary unification. The supply function, which is based on Martin (1997), stresses the importance of cross-border spillovers. When negative supply shocks occur, countries compete for economic activity through tax cuts and surprise inflation. At the same time, they want to achieve a certain level of government spending and they want to maintain price stability. So the authorities in each country face a policy dilemma. I extend Martin’s basic model in a number of ways. The model consists of three rather than two countries, and fiscal authorities are explicitly modeled. This makes it possible to consider the interactions between monetary and fiscal policymakers and between EMU participants and third countries. Furthermore, I allow for commitment problems and I provide a (simple) behavioural motivation for the supply curves.

For the welfare evaluation, this chapter uses a framework developed by Beetsma and Bovenberg (1999b). They investigate the trade-off between credibility and flexibility in a monetary union with decentralised fiscal policy-making and they study the optimal design of monetary institutions. Their 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, the inability of fiscal policymakers to commit leads to an upward bias in the expected tax rate, which increases the welfare cost of structural distortions. Secondly, 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.
With respect to the welfare consequences of EMU, I conclude that the welfare effect of EMU for Europe is ambiguous within this modelling framework. 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 the 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 (they lose the possibility to have different monetary policies in individual euro area countries in response to asymmetric shocks). This makes it more difficult to attain policy goals, which is welfare-reducing. The net welfare impact of EMU on Europe depends on the relative importance of low inflation versus the other government policy goals (stable output and spending) and on the variance of shocks. The beneficiary effect will be larger when the authorities are more activist and when the variance of shocks is low. 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 chapter is organised as follows. In the next section, I present 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 3.3, 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 3.4 concludes this chapter.

**3.2 Benchmark case: A two-country model**

In this section, a two-country monetary-fiscal policy game is developed and analysed in some detail. Crucial elements are the presence of international spillovers and the assumption that monetary and fiscal policymakers are unable to commit. These elements will turn out to affect the welfare cost of structural distortions and unanticipated shocks. Furthermore, the two-country model serves as a benchmark for the analysis of the impact of EMU, using a three-country model, in section 3.3.
3.2.1 Output

The world consists of two identical countries, named euro area (denoted by a subscript $E$) and United States (denoted by a subscript $S$). 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 logs) is derived in Appendix A:

$$y_E = -kt_E - (w_E - p_E + t_E - t_E^*) + (w_S - p_S + t_S - t_S^*) + \varepsilon_E,$$

$$y_S = -kt_S^* + (w_E - p_E + t_E - t_E^*) - (w_S - p_S + t_S - t_S^*) + \varepsilon_S,$$

where $y$, 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, $t_i^*$ is the expected output tax rate, $k$ is a constant and $\varepsilon_i$ is a random supply shock. With $E\varepsilon_i = 0$, $\text{Var}(\varepsilon_i) = \sigma^2$, $E\varepsilon_i\varepsilon_j = 0$, for $i, j = E, S$ and $i \neq j$. 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, I will assume $k > 2$ there. The latter assumption will be used throughout the article.

We can motivate the supply functions in this article as follows. Firms are perfectly competitive. The representative firm is a multinational company with production sites in both 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 have been set, the firm can relocate workers among countries.1 Thus, firms can relocate their production from one country to another and will choose to increase production relatively more in the country that has a lower real wage and where output taxes are lower. 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 it should be stressed that the model does not formally distinguish between a short run and a long run). It is the story on which the derivation of equations (3.1)-(3.2) is based, but note that these supply functions are probably consistent with many stories.

1The assumption that workers on existing contracts can be relocated, but that no new workers can be hired in the short run is arguably more realistic for high-skilled than for low-skilled workers. The supply of high-skilled workers can said to be fixed in the short run, since skills can only be acquired through training. Moreover, high-skilled workers tend to be more mobile internationally than low-skilled workers. See, for instance, McCormick (1997) or Mauro and Spilimbergo (1999) for evidence.
3.2. Benchmark case: A two-country model

Before discussing these supply curves further, 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).

The main characteristics of the above functions for supply per capita are as follows. First, output is negatively correlated with the real wage rate (i.e. an inflation surprise) and a tax surprise in the home country. My supply curve shares this feature with almost every other supply curve in the literature.\(^2\) Second, output is positively correlated with a foreign inflation surprise and a foreign tax surprise. Foreign policy surprises appear in the home supply curve because they occur before firms hire workers. An increase in the foreign real wage or tax rate will induce firms to reduce output in the foreign country, but the fact that the workers cannot be laid off implies that a reduction of output in the foreign country must be accompanied by a shift of workers to the home country, which leads to an increase of output in the home country. In other monetary-fiscal models, taxes enter the supply function, but foreign variables usually do not.\(^3\) Third, output is negatively related to the domestic expected tax rate.\(^4\) A higher expected tax rate will lead a firm to reduce output in the country concerned, but has no impact on the optimal level of output in the other country. Because expectations are formed before firms hire workers, there is no need to shift workers to another country in response to a higher expected tax rate. Therefore, the expected domestic tax rate enters the supply curve, but the expected foreign tax rate does not. Fourth, note that output is more responsive to the expected tax rate than to a tax surprise. This characteristic will be explained in more detail when discussing the fiscal commitment problem in section 3.2.5. In other monetary-fiscal models, the response of output to the domestic expected tax rate is often implicitly assumed to equal unity (i.e. \(k = 1\)).

Workers set the nominal wage such as to achieve a target real wage. They do this based on rational expectations with respect to the inflation rate. After substituting the optimal wage rule \((w_t = p_t^f, \text{ see Appendix A for derivation})\), we find the following

\(^2\)A commonly used supply function is \(y = \alpha(p - w - t)\). See, for instance, Alesina and Tabellini (1987). The basic equation is of the form \(y = b[p_t - E(p_t|t)]\) and is due to Lucas (1973). See also Blanchard and Fischer (1989, chapter 7).

\(^3\)The monetary game presented by Martin (1997) is an exception, but there are no fiscal authorities in his model.

\(^4\)Equilibrium output is affected by the expected tax rate, but not by the expected inflation rate. The reason is that, by adjusting nominal wages, workers can prevent that changes in the expected inflation rate affect the real wage rate, whereas firms cannot prevent that changes in the expected tax rate affect firm profits.
equations for supply per capita: \(^5\)

\[
\begin{align*}
y_E &= -kt'_E + (\pi_E - \pi'_E - t_E + t'_E) - (\pi_S - \pi'_S - t_S + t'_S) + \varepsilon_E. \\
y_S &= -kt'_S - (\pi_E - \pi'_E - t_E + t'_E) + (\pi_S - \pi'_S - t_S + t'_S) + \varepsilon_S.
\end{align*}
\]

(3.3) \quad (3.4)

where \(\pi_i\) is the log increase in the general price level, \(i = E, S\).

In the absence of tax distortions and shocks, \(^6\) \(y_i = 0\) 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 an inflation surprise (\(\pi_i \neq \pi'_i\)) and a tax surprise (\(t_i \neq t'_i\)) 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 ‘shift terms’ in equations (3.3)-(3.4) cancel out in the formula for world output per capita. Unexpected monetary and fiscal policy changes are neutralised at the world level: one country’s gain is another country’s loss. Arguably, it would have been more realistic to assume an upward-sloping world supply curve. However, for reasons of simplicity, I assume that the world supply curve is vertical. This implies that we focus on shifts of economic activity, neglecting the possibility that policy surprises may increase world output. \(^7\)

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.

\(^5\)I have also used \(\pi_i - \pi'_i = [\pi_i - (\pi_i-1)] - [\pi'_i - (\pi'_i-1)] = \pi_i - \pi'_i\).

\(^6\)That is: if \(t_i = t'_i = 0\) and \(\varepsilon_i = 0\).

\(^7\)A more general version of the supply functions would be

\[
\begin{align*}
y_1 &= -kt'_1 + (\pi_1 - \pi'_1 - t_1 + t'_1) - l(\pi_2 - \pi'_2 - t_2 + t'_2) + \varepsilon_1, \\
y_2 &= -kt'_2 - l(\pi_1 - \pi'_1 - t_1 + t'_1) + (\pi_2 - \pi'_2 - t_2 + t'_2) + \varepsilon_2.
\end{align*}
\]

For \(l = 0\), there would be no international spillovers. For \(l > 0\), international spillovers are non-trivial and countries (governments) compete for being the most attractive production site. For \(l = 1\), spillovers are complete and the competition between countries is a zero-sum game: policy surprises affect output in each individual country, but will not affect world-wide output. For a relatively small country, one could even imagine \(l > 1\). For instance, Canadians are fond of saying: ‘When the US catches cold, Canada catches pneumonia’, reflecting their belief that US shocks have a magnified effect on the Canadian economy. Arguably, \(0 < l < 1\), when spillovers are partial, is the most realistic scenario. However, this chapter will look at the simpler case \(l = 1\).
This article looks at supply shocks only. Examples of such unanticipated shocks are oil price shocks and a credit crunch. Supply shocks pose a bigger dilemma for central banks in terms of the trade-off between inflation and output than demand shocks. In the case of demand shocks, a monetary policy that aims at price stability automatically dampens output fluctuations. In the case of supply shocks, prices and output are negatively correlated, so that a monetary policy geared at short-run price stability could adversely affect the output gap. The bigger monetary policy dilemma means that supply shocks are the more interesting case. Moreover, Bayoumi and Eichengreen (1993) find empirically that international spill-overs on the demand side are unimportant when compared to spill-overs on the supply side.  

### 3.2.2 Policymakers

Fiscal authorities prefer inflation to be as close as possible to zero and to keep output and spending close to their target level. They set taxes and spending in order to minimise

\[
L_i^F = \frac{1}{2} [\pi_i^2 + \gamma(y_i - y_i^*)^2 + \phi(g_i - g_i^*)^2], \quad i = E, S. \tag{3.5}
\]

which corresponds to the loss function of society. The preferred inflation rate is normalised to zero (i.e. \(\pi_i^* = 0, i = E, S\)), the output target is equal to its first-best level \(y_i^*\) and \(g_i\) is the level of government spending as a share of non-distortionary output (i.e. the 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 \(\gamma\) and \(\phi\ (>0\) indicate the relative weight attached to the different policy goals by the government.

High values of \(\frac{\gamma}{\phi}\) reflect the preferences of a government, whose main goal would be to keep the economy close to trend economic growth. Such a government is likely to be ‘activist’, in the sense that it will actively use the level of taxation to stabilise output. Relatively low values of \(\frac{\gamma}{\phi}\) reflect the preferences of a government which finds it important to maintain government spending (as a share of output) at a certain level.

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8 Bayoumi and Eichengreen state that: ‘With respect to supply shocks, in both Europe and the US there is a ‘core’ region [...] where the shocks are highly correlated [...] With respect to demand shocks [in Europe] [...] the correlation with Germany is much lower, even for the other countries of the European core.’

9 Recent models provide micro-foundations for the incorporation of inflation in the welfare function. See, for instance, Woodford (2001).

10 Alternatively, the coefficient \(\phi\) can be seen as capturing the fact that fiscal policy is difficult to fine-tune relative to monetary policy (Eichengreen and Ghironi, 1999).
even in the face of large output fluctuations. It will be assumed that $\phi$ and $\gamma$ are equal across countries. However, the targets $y^*_i$ and $g^*_i$ may differ across countries.\footnote{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 level of potential output by a policy of ‘small government’ and a low level of taxation, in order not to create too many distortions. I 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.}

The government budget constraint is:\footnote{In this paper, the terms government and fiscal authorities are used interchangeably.}

$$g_i = t_i + \mu \pi_i, \quad i = E, S. \quad (3.6)$$

where $\mu (>0)$ represents the (constant) ratio of real money holdings as a share of the first-best level of output in equilibrium.\footnote{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 constraint, which includes the possibility of non-zero government debt.}

When adverse shocks occur, each central bank has an incentive to reduce the domestic real wage and each government has an incentive to cut taxes in order to import jobs and production from the foreign country (Martin, 1997). Governments do this because attracting workers from abroad increases the level of output relative to population size, taking output per capita closer to its target level. Cutting taxes and creating inflation are beggar-thy-neighbour policies in this model, in the sense that they harm foreign output [see equations (3.3)-(3.4)].

Monetary policy is delegated to central banks, who try to steer the economy so as to keep inflation close to price stability and output close to its target. 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:

$$L^{CB}_i = \frac{1}{2} \left[ \pi_i^2 + \beta (y_i - y^*_i)^2 \right]^2, \quad i = E, S. \quad (3.7)$$

The parameter $\beta (>0)$ 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 $\beta (>0)$ attached to this goal may differ from the governments’ preference ($\gamma$).\footnote{The loss function (3.7) comes close to the trade-off which the Federal Reserve is supposed to make.} Clarida, Galí and Gertler (1998) provide empirical evidence that the monetary policy reaction functions for the largest industrialised
countries are quite similar. This suggests that it is not unreasonable to assume that $\beta$ 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 have been formed.

### 3.2.3 Framework for welfare evaluation

Making use of equation (3.1), the euro area government budget constraint can be rewritten as follows:

$$y_E + g_E - \varepsilon_E + (k-1)t_E^* = (y_E^* - y_E) + (g_E^* - g_E) + \mu \pi_E +$$

$$+ (\pi_E - \pi_E^*) - (\pi_S - \pi_S^*) + (t_S - t_S^*). \quad (3.8)$$

The left hand side of equation (3.8) contains the ‘financing requirement’. The first three terms are exogenous distortions to the euro area. The exogenous distortions consist 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 euro area. So far, the left hand side is identical to Beetsma and Bovenberg (1999b). The fourth term on the left hand side [the expected tax level, multiplied by $(k - 1)$] is new. 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 and makes it more difficult to meet policy objectives. Conversely, an expected subsidy (a negative expected tax rate) would have a stimulative impact on output and contribute to meeting the objectives. Together, the terms on the left hand side can be seen as the ‘financing requirement’ faced by the domestic authorities when they make policy decisions.

The right hand side of equation (3.8) provides insight into the tradeoff to be made by euro area and US authorities. The first three terms correspond to the three components in the loss functions of the euro area fiscal authority. The authorities use tax and inflation

It can also be interpreted as the trade-off for the European Central Bank between sticking to the goal of price stability as defined in the EU Treaty and giving in to more short-term goals that politicians may press for. It seems also realistic to assume that monetary decision makers attach at least some positive weight to avoiding recessions ($\beta > 0$), even when the central bank is fully independent from the government and when its only statutory goal is price stability.
policies in order to attain the optimal distribution of the financing requirement [the left-hand side of equation (3.8)] 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 two terms are new. They represent policy moves by the United States authorities in response to stochastic shocks. Such policies are intended to be stabilising for the US, but they are beggar-thy-neighbour in the sense that they may lead to a shift of economic activity from the euro area to the US, which makes it more difficult for the euro area fiscal authorities to meet the policy objectives.

3.2.4 Solution of the model

Henceforth, the ECB is the monetary authority and the Council of Ministers ('Ecofin') is the fiscal authority of the euro area. The Federal Reserve is the monetary authority and the Treasury is the fiscal authority of the United States. Due to the symmetry of the model, it suffices to solve the model for euro area variables. The expressions for US variables are found by switching the country indices of all variables in the equations.

All policy makers play Nash against each other. Substituting the supply curve (3.3) and the government budget constraint (3.6) into the loss function of the Ecofin (3.5) and minimising with respect to the euro area tax rate (its policy instrument) gives the first-order condition for the Ecofin:

$$
\phi(g_E - g^*_E) = \gamma(y_E - y^*_E).
$$

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 (defined as the difference between actual output and the output target: $y_E - y^*_E$) and the government spending gap (defined as the difference between the actual and the first-best level of government spending: $g_E - g^*_E$) in a ratio $\frac{\gamma}{\phi}$. The burden of adjustment which falls on output is $\frac{\gamma}{\phi}$ times as large as the burden of adjustment which falls on government spending.

Substituting the euro area supply curve (3.3) into the loss function of the ECB (3.7) and minimising with respect to euro area inflation, which is the ECB's policy instrument,\(^{15}\)

\(^{15}\)In the two-country case, the expected tax rate ($t'_{E}$) appears in the equation, whereas the actual tax rate ($t_E$) is only implicitly present (in the term $-g_E + \mu\pi_E$). This is due to the chosen normalisation. In the three-country case, which will be introduced in section 3.3, the tax rate will appear in the equation with a non-zero coefficient.
gives the first-order condition for the ECB:
\[ \pi_E = -\beta(y_E - y_E^*) \].

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 and inflation in a ratio \( \frac{1}{\beta} \). Thus, the deviation from the output target is \( \frac{1}{\beta} \) times as large as the deviation from price stability.

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 (3.8) is derived in appendix B and shown in Table 1. In Table 1, each variable has been decomposed in a deterministic and a stochastic component.

Table 1  Solution to the two-country game under monetary and fiscal discretion

<table>
<thead>
<tr>
<th>variable</th>
<th>deterministic component</th>
<th>stochastic component</th>
</tr>
</thead>
<tbody>
<tr>
<td>( y_E^* - y_E )</td>
<td>( \frac{\phi}{\phi + k(\phi \beta + \gamma)}[g_E^* + y_E^* + (k-1)g_E^*] )</td>
<td>(- (A_1 \varepsilon_E + A_2 \varepsilon_S))</td>
</tr>
<tr>
<td>( g_E^* - g_E )</td>
<td>( \frac{k\gamma}{\phi + k(\phi \beta + \gamma)}[g_E^* + y_E^* - (\frac{k-1}{k})y_E^*] )</td>
<td>(- \frac{2}{\phi}(A_1 \varepsilon_E + A_2 \varepsilon_S))</td>
</tr>
<tr>
<td>( \mu \pi_E )</td>
<td>( \frac{k\mu \beta}{\phi + k(\phi \beta + \gamma)}[g_E^* + y_E^* - (\frac{k-1}{k})y_E^*] )</td>
<td>(- \mu \beta(A_1 \varepsilon_E + A_2 \varepsilon_S))</td>
</tr>
<tr>
<td>(- (k-1)t_E^*)</td>
<td>( \frac{k(\phi \beta + \gamma)}{(k-1) \phi + k(\phi \beta + \gamma)}(k-1)g_E^* )</td>
<td>0</td>
</tr>
<tr>
<td>( \pi_E - \pi_E^* )</td>
<td>0</td>
<td>(- \beta(A_1 \varepsilon_E + A_2 \varepsilon_S))</td>
</tr>
<tr>
<td>(- (\pi_S - \pi_S^*))</td>
<td>0</td>
<td>( \beta(A_2 \varepsilon_E + A_1 \varepsilon_S))</td>
</tr>
<tr>
<td>( t_S - t_S^* )</td>
<td>0</td>
<td>( \frac{\phi \beta(1 + \mu)}{\phi}(A_2 \varepsilon_E + A_1 \varepsilon_S))</td>
</tr>
</tbody>
</table>

where
\[ A_1 = \frac{\phi + H}{\phi + 2H}; \quad A_2 = \frac{H}{\phi + 2H}; \quad H = \phi \beta(1 + \mu) + \gamma. \]

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, whereas the presence of international spillovers plays an important role in interpreting the stochastic components.

### 3.2.5 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.\(^\text{16}\)

The issue of (non-)commitment plays a key role. I will, realistically, assume that policymakers are unable to commit. The reason is that such commitments are not enforceable.\(^\text{17}\)

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. By generating an inflation surprise, the monetary authorities can influence the real wage rate in an attempt to cause a shift in activity. Workers are aware of the fact that the monetary authorities have an incentive to let inflation increase after private inflation expectations are formed. Thus, the absence of monetary policy commitment gives rise to an upward inflation bias.

---

\(^{16}\)If $y^*_E$ is relatively large compared to $g^*_E$, the expected tax rate could actually be negative. Intuitively, if the desired level of government spending is close to zero, it may be optimal for the government to hand out an output subsidy (financed by seigniorage) in order to offset non-tax distortions.

\(^{17}\)An independent central bank can promise not to create surprise inflation, but private agents cannot punish the central bank if it breaks this promise. Similarly, the government of a sovereign country can promise not to raise taxes, but private agents cannot punish the government for doing so anyway. The government can be voted out of office only once every four years and the new government, once in office, may quickly forget its own (or the previous government's) election promises. The standard references on the time-inconsistency problem are Kydland and Prescott (1977) and Barro and Gordon (1983).
Fiscal policy is subject to a time-inconsistency problem as well. The fiscal time-inconsistency arises because firms hire workers before shocks occur and policies are set. An increase in the domestic tax rate implies a decline in the after tax marginal product of labour, so that it is optimal to reduce the amount of labour in the home country. In the absence of any restrictions on the number of workers, the optimal amount of labour in the foreign country would not be affected. However, after firms have hired employees (which cannot be laid off, so that the worldwide number of workers is effectively fixed), a reduction in the amount of labour in the home country must be accompanied by an equally large increase in the amount of labour in the foreign country. The additional foreign output must be sold at a loss, so that, effectively, the constraint on the total (worldwide) number of workers makes it more costly for firms to reduce production in the home country. Therefore, output is less responsive to a surprise tax increase (which occurs after workers have been hired) than to an expected tax increase (which occurs before workers are hired). This causes the fiscal time-inconsistency: the fiscal authorities have an incentive to promise a low tax rate (to attract activity) and to raise the tax rate (to enable additional government spending) once firms have chosen the location of production. Firms are aware of this incentive. Thus, 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 it should be stressed that the model does not formally distinguish between the short run and the long run). Short-run constraints can be related to labour contracts (as in this paper), but can also be due to the cost of reversing capital investments made. 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 firms have made substantial investments in the country.

In Alesina and Tabellini (1987), tax rates enter the supply curve, but fiscal policy is not subject to time-inconsistencies. In Bryson, Jensen, Van Hoose (1993), fiscal policy...
is subject to time-inconsistencies. In their model, as in mine, expected and unexpected tax cuts stimulate output in the home country.\footnote{In Bryson et al. (1993), firms are nationally based but sell their output both domestically and abroad, so that tax cuts in any country boost home firm output, whereas in this paper firms produce in all nations, so that home output responds positively to home tax cuts and negatively to foreign tax cuts.} 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.

As argued, the assumption that policy makers cannot credibly commit to a certain policy leads to an upward bias in the inflation rate and the tax rate. In this article, monetary policy is delegated to an independent central bank in each country. Under decentralised policy-making central banks ignore the role of seigniorage as a source of government revenues, which reduces the inflation rate in equilibrium. Thus, one type of distortion (non-commitment) is partially solved by introducing another distortion (decentralised policy-making), in line with the theory of the second-best.\footnote{As shown by Rogoff (1985b), society may be better off by appointing an independent central banker whose preferences diverge from those of society. Also see Alesina and Tabellini (1987) and DeBell and Fischer (1994).} The impact of commitment in the model is analysed in more detail in appendix B.\footnote{Appendix B starts with the two-country model with full commitment and centralised policy-making in each country and then introduces the distortions (decentralised policy-making, fiscal credibility problem, monetary credibility problem) one by one.}

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 ($k > 1$, see Appendix A). 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 (3.8). This indicates that the upward tax 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 \( (\phi, \gamma) \) and the central bank \( (\beta) \) and on the importance of seigniorage to the government budget \( (\mu) \).

A fiscal authority which is inclined to close the output gap rather than the spending gap \( (\frac{\beta}{2} \text{ high}) \) 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.

A less conservative central bank \( (\beta \text{ high}) \) 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.

A larger real money stock \( (\mu \text{ higher}) \) means that there is a larger 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 need for the central bank to raise inflation in order to protect employment.

### 3.2.6 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 \( \varepsilon_S \), but not by US distortions \( g_3^* \) and \( y_5^* \). This follows from the assumption that shocks (and the response of policymakers) realise after firms have hired workers, whereas distortions are known to firms before they hire workers. 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 (3.8). Inflation surprises cannot contribute to the financing of the determinis-
tic component, because wage-setters have rational expectations and thus anticipate the effect of the deterministic distortions on inflation when setting wages. However, wage-setters cannot anticipate the effect of stochastic shocks, because shocks occur only after wage contracts have been signed. Therefore, an inflation surprise can be used to shift part of the burden of a stochastic shock to (domestic and foreign) private sector agents. Inflation surprises, therefore, can contribute to the ‘financing’ of stochastic shocks. Conversely, foreign policy responses to shocks to the euro area economy enhance the need for the euro area 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 may more than offset the contribution of a domestic inflation surprise to financing the stochastic component.

For instance, suppose that, as a result of adverse weather conditions in the US. labour productivity in the agricultural and construction sectors drops dramatically. The Federal Reserve decides to create surprise inflation and the US government decides for a surprise tax cut. It becomes attractive for firms to shift output towards the United States. This buffers the initial fall in US output, at the cost of lower output in Europe. The European policymakers anticipate the negative spillovers and decide to ease their monetary and fiscal policy stance as well, albeit to a lesser extent. This causes a second-round (negative) spillover of output in the other direction. In equilibrium, all policymakers over-respond to the initial shock, resulting in a sub-optimal outcome.

### 3.2.7 Welfare

The euro area’s welfare loss follows upon substitution of the solutions for $y_E^* - y_E$, $g_E^* - g_E$ and $\mu \pi_F$ into equation (3.5):

$$L_E = \frac{1}{2} (\delta^2 + \gamma + \gamma^2) \left[ \frac{\phi}{\phi + k(\phi \mu \beta + \gamma)} (kg_E^* + y_E^*) - (A_1 \varepsilon_E + A_2 \varepsilon_S) \right]^2. \tag{3.12}$$

Recall that the distortions $g_E^*$ and $y_E^*$ are non-stochastic. The stochastic shocks $\varepsilon_E$ and $\varepsilon_S$ have zero expected value and are uncorrelated with each other. Therefore, the equilibrium expected welfare loss of the euro area is:

$$E(L_E) = \frac{\phi \delta^2 + \phi \gamma + \gamma^2}{2\phi} \left[ \frac{\phi^2}{(\phi + k(\phi \mu \beta + \gamma)k \gamma)^2} (kg_E^* + y_E^*)^2 + \frac{(\phi + H)^2 + H^2}{(\phi + 2H)^2 - \sigma^2} \right]. \tag{3.13}$$

The euro area authorities respond to the composite shock $A_1 \varepsilon_E + A_2 \varepsilon_S$. In the absence of international spillovers, they would respond to the shock $-\frac{\phi}{\phi + H} \varepsilon_E$, i.e. their response to the domestic shock $\varepsilon_E$ would be more moderate (note that $-\frac{\phi}{\phi + H} < A_1$) and they would not respond to the foreign shock $\varepsilon_S$ at all.
Society’s welfare is thus composed of a term arising from deterministic distortions and a term associated with stochastic (supply) shocks. 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, which increases the welfare cost of structural distortions.\(^{26}\) 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.

Beetsma and Bovenberg (1999b) point out that inflation surprises can contribute to financing the stochastic component and not to financing the deterministic component. Therefore, it is less costly to finance stochastic shocks than deterministic distortions in their model. In the current model, 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. This can be seen by comparing the coefficients of \((k g_E^* + y_E^*)^2\) and \(\sigma^2\) in equation (3.13). It turns out that stochastic shocks are more costly than deterministic distortions in the context of this model, unless central banks are activist and fiscal authorities and central banks pursue different goals.\(^{27}\) Thus, the assertion by Beetsma and Bovenberg that it is less costly to finance stochastic shocks does not necessarily hold here.

\(^{26}\)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 has been studied by many others, it does not require much attention here.

\(^{27}\)Assume seigniorage to be unimportant (i.e. \(\mu \rightarrow 0\)). This is fairly realistic for Europe and the US. Then it is easy to show that the coefficient of \(\sigma^2\) is larger than the coefficient of \((k g_E^* + y_E^*)^2\), unless \(\beta\) is sufficiently large (i.e. central banks care much about stabilising output) and \(\sigma/\gamma\) is sufficiently large (i.e. governments care relatively more about the level of government spending than about stabilising output).
3.3 Monetary unification: A three-country model

In this paragraph, we will analyse the impact of the centralisation of monetary policy in Europe. Therefore, the model will be extended to a three-country version. For simplicity, Europe consists of Germany and France. 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.

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.

3.3.1 Floating rates

Model specification

Supply per capita is:\(^{28}\)

\[
\begin{align*}
  y_G & = -kt_G + 2(\pi^d_G - t^d_G) - (\pi^d_F - t^d_F) - (\pi^d_S - t^d_S) + \varepsilon_G, \quad (3.14) \\
  y_F & = -kt_F - (\pi^d_G - t^d_G) + 2(\pi^d_F - t^d_F) - (\pi^d_S - t^d_S) + \varepsilon_F, \quad (3.15) \\
  y_S & = -kt_S - \frac{1}{2}(\pi^d_G - t^d_G) - \frac{1}{2}(\pi^d_F - t^d_F) + (\pi^d_S - t^d_S) + \varepsilon_S. \quad (3.16)
\end{align*}
\]

where \( x^d = x - x^e \), i.e. \( x^d \) is the deviation of a variable \( x \) from its expected value. Effectively, the euro area supply function has been desaggregated into the German and French supply functions. Assuming common monetary and tax policies and common shocks in Germany and France would reduce the system (3.14)-(3.16) to the two-country supply functions (3.3)-(3.4).

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

---

\(^{28}\)The supply curves (3.14)-(3.16), which take into account the relative size of countries, are derived in Appendix A. Note that output is more responsive to domestic policy surprises in Germany and France than in the US. This follows from relative country size, as explained in appendix A. Applying the size argument consistently would argue 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) would argue 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.
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:

\[
\frac{y_G + y_F}{2} + y_S = -k \left( \frac{t_G^* + t_F^*}{2} \right) - kt_S^* + \frac{\varepsilon_G + \varepsilon_F}{2} + \varepsilon_S. \tag{3.17}
\]

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

**Solution of the model under floating rates**

Substituting the supply curves into the loss functions of the central banks and minimising with respect to each central bank’s policy instrument (domestic inflation), gives the first-order conditions for the Bundesbank, the Banque de France and the Federal Reserve:

\[
\pi_i = -2\beta(y_i - y_E^*), \quad i = G, F, \tag{3.18}
\]

\[
\pi_S = -\beta(y_S - y_S^*). \tag{3.19}
\]

The Federal Reserve will tend to choose a lower inflation rate 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.\(^{29}\)

Substituting the supply curves and the government budget constraints into the loss functions of the fiscal authorities and minimising with respect to their policy instruments (the domestic tax rates) gives the first-order condition for the fiscal authorities:

\[
\phi(g_i - g_E^*) = 2\gamma(y_i - y_E^*), \quad i = G, F, \tag{3.20}
\]

\[
\phi(g_S - g_S^*) = \gamma(y_S - y_S^*). \tag{3.21}
\]

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.

The German government budget constraint can be rewritten in order to obtain the three-country equivalent of equation (3.8):

\[
y_E^* + g_E^* - \varepsilon_G + (k - 1) t_G^* = (y_E^* - y_G) + (g_E^* - g_G) + \mu \pi_G + 2(\pi_G - \pi_G^*) - (t_G - t_G^*) + - (\pi_F - \pi_F^*) + (t_F - t_F^*) + -(\pi_S - \pi_S^*) + (t_S - t_S^*). \tag{3.22}
\]

\(^{29}\)See Martin (1997) and chapter 2 of this dissertation.
The left hand side of equation (3.22) contains the ‘financing requirement’ of the German economy, whereas the right hand side of equation (3.22) provides insight into the tradeoffs to be made by policy makers. As in the two-country version of the model, a tax surprise and an inflation surprise can be used to finance part of the burden of a stochastic shock, but not for deterministic distortions. The foreign policy responses to an adverse supply shock may increase the burden of adjustment for the home country.

The full solution to the game is derived and reported in appendix C (Table C1). Its form is essentially the same as for the two-country case.

Welfare under floating rates

The equilibrium expected welfare loss for Germany and France is:

\[
E(L_i) = \frac{4 \phi \beta^2 + \phi \gamma + 4 \gamma^2}{2 \phi} \left\{ \frac{\phi^2}{(\phi + 2k \phi \mu + 2k \gamma)^2} (k g^*_E + y^*_E)^2 + \right.
\]
\[
+ \left[ \frac{\phi (\phi + 3H)}{\phi + 6H} \right]^2 + \frac{H(2\phi + 3H)}{(\phi + 6H)^2} \right\} \sigma^2, \quad i = G, F. \tag{3.23}
\]

The equilibrium expected welfare loss for the US is:

\[
E(L_S) = \frac{\phi \beta^2 + \phi \gamma + \gamma^2}{2 \phi} \left[ \frac{\phi^2}{(\phi + k \phi \mu + k \gamma)^2} (k g^*_S + y^*_S)^2 + \right.
\]
\[
+ \left( \frac{\phi + 2H}{\phi + 3H} \right)^2 \right\} \sigma^2. \tag{3.24}
\]

Whether financing the deterministic component is more or less costly in terms of welfare than financing the stochastic component is ambiguous in general. 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.

A unit increase in the desired level of government spending \( g^*_E \), \( g^*_S \) (which leads to an increase in the expected tax rate) is more costly in terms of welfare than a unit increase in the level of non-tax distortions \( y^*_E \), \( y^*_S \) (which leads to a lower expected tax rate). The relative costliness of government spending is reflected in the term \( k \ (> 2) \) before \( g^*_E \) and \( g^*_S \).

---

\(^{30}\)The inability of fiscal policymakers to commit causes an upward tax bias. This does not imply that the expected tax rate is necessarily positive. It only implies that the expected tax rate will be more positive, or less negative, than under fiscal commitment. Nevertheless, a positive expected tax rate seems to be the most relevant case in practice.
3.3.2 EMU

Model specification

Under EMU, monetary policy in Europe is centralised, but fiscal policy is determined at the national level. The combination of a single monetary policy, a perfect substitutability of goods and the absence of trade barriers 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 $\pi_E$. Substituting the common inflation rate into equations (3.14)-(3.16) gives the supply curves for Germany, France and the United States under EMU

$$y_G = -kt_G + 2(\pi_E^d - t_G^d) - (\pi_E^d - t_E^d) - (\pi_S^d - t_S^d) + \varepsilon_G,$$  \hspace{1cm} (3.25)$$

$$y_F = -kt_F + 2(\pi_E^d - t_F^d) - (\pi_E^d - t_F^d) - (\pi_S^d - t_S^d) + \varepsilon_F,$$  \hspace{1cm} (3.26)$$

$$y_S = -kt_S^d - \frac{1}{2}(\pi_E^d - t_E^d) - \frac{1}{2}(\pi_S^d - t_S^d) + \varepsilon_S.$$  \hspace{1cm} (3.27)$$

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

$$y_E = \frac{1}{2}(y_G + y_F) =$$

$$= -k \left(\frac{t_G^* + t_F^*}{2}\right) + \left(\pi_E^d - \frac{t_G^d + t_F^d}{2}\right) - \left(\pi_S^d - t_S^d\right) + \frac{\varepsilon_G + \varepsilon_F}{2}. \hspace{1cm} (3.28)$$

Under EMU, the ECB and the Fed minimise:\footnote{I implicitly assume that the members of the ECB Governing Council, who determine euro area monetary policy, look at euro area variables only. Alternatively, I could have assumed that 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 Bénassy-Quéré et al. (1997, p. 164) for a proof.}

$$L_E^{CB} = \frac{1}{2} \left[\pi_E^2 + \beta(y_E - y_E^*)^2\right], \hspace{1cm} (3.29)$$

$$L_S^{CB} = \frac{1}{2} \left[\pi_S^2 + \beta(y_S - y_S^*)^2\right]. \hspace{1cm} (3.30)$$

The earlier assumption of equal distortions in euro area member states ensures that the first-best level of euro area output per capita is equal to the first-best output per capita levels for Germany and France individually.

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

\[ g_i = l_i + \mu \pi_E, \quad i = G, F, \]  
\[ g_S = l_S + \mu \pi_S. \]  

(3.31)  
(3.32)

The fiscal authorities minimise the following loss functions:

\[ L_i^F = \frac{1}{2}[\pi_E^2 + \gamma(y_i - y_E^*)^2 + \phi(g_i - g_E^*)^2], \quad i = G, F. \]  
\[ L_S^F = \frac{1}{2}[\pi_S^2 + \gamma(y_S - y_S^*)^2 + \phi(g_S - g_S^*)^2]. \]  

(3.33)  
(3.34)

**Solution of the model under EMU**

Substituting the supply curves (3.27) and (3.28) into the loss functions of the central banks (3.29)-(3.30) and minimising with respect to each central bank's policy instrument (domestic inflation), gives the first-order conditions for the ECB and the Federal Reserve:

\[ \pi_E = -\beta(y_E - y_E^*), \]  
\[ \pi_S = -\beta(y_S - y_S^*). \]  

(3.35)  
(3.36)

The centralisation of monetary policy in Europe is reflected in the first-order condition for the ECB. It differs from those of the Bundesbank and the Banque de France under floating rates [equation (3.18)], but is identical to the condition for the Federal Reserve [equation (3.19)]. The ECB will tend to choose a lower inflation rate 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. Under 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. Under EMU, the euro area national central banks cannot attract economic activity from the other euro area country through an inflation surprise. Hence, the inflation response to unanticipated shocks is smaller: the ECB is less aggressive in its attempts to shift part of the burden of supply shocks abroad. As a by-product, the United States is hindered less by European beggar-thy-neighbour policies. It should be stressed that the ECB keeps inflation closer to zero, not because the ECB is more inflation averse, but because

\[ \text{Note that seigniorage revenue in the German and French budget constraints (23a)-(23b) is now based on euro area, rather than national inflation.} \]
3.3. Monetary unification: A three-country model

of the possibility of the participating central banks to commit against each other, which allows them to internalise policy-making externalities.\(^\text{33}\)

Substituting the supply curves (3.25)-(3.27) and the government budget constraints (3.31)-(3.32) into the loss functions of the fiscal authorities (3.33)-(3.34) and minimising with respect to their policy instruments (domestic tax rates) gives the first-order condition for the fiscal authorities. These conditions are identical to the first-order conditions for the fiscal authorities under floating rates, since fiscal policy in the euro area is still decentralised.

In Appendix C, first the solution to the game in terms of the policymakers' instruments (inflation and taxes) is derived, then the results are combined with the supply functions and budget constraints to yield the solution in terms of the determinants of welfare and the other variables in the EMU analogon of equation (3.22).\(^\text{34}\) The full solution is reported in Table C2.

3.3.3 Impact of monetary unification

Macroeconomic effects of EMU

There are several differences between EMU and floating rates in Europe. Most importantly, EMU causes intra-European spillovers in monetary policy to be internalised. Under floating rates the Bundesbank and the Banque de France will endeavour to achieve their output target by causing beggar-thy-neighbour surprise inflation. Under EMU, part of this incentive will be internalised: the ECB still has the incentive to conduct a beggar-thy-neighbour policy against the United States, but no longer within Europe. This leads to a lower inflation bias.

EMU has two seigniorage-related effects. First, the lower inflation bias leads to a lower level of seigniorage income, which makes it more difficult to attain the governments' policy targets for output and government spending. Second, seigniorage is shared between the euro area governments. The euro area fiscal authorities know that a tax cut will induce a tighter 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 unimportant in practice.


\(^{34}\)The EMU analogon of (3.22) is simply found by substituting \(\pi_E\) for \(\pi_G\) and \(\pi_F\).
given the limited significance of seigniorage as a source of government revenue in the euro area (as in the United States).

Now, let us turn to the response to shocks. Under EMU, there is a single inflation rate in the euro area, which is affected by French and German shocks to an equal extent, as monetary policy cannot be directed at country-specific circumstances. Instead, it is determined by euro area averages. 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 output, and secondly, German shocks are less important to the ECB than to the Bundesbank.\(^\text{35}\) Whether the ECB will be more or less responsive to French shocks than the Bundesbank is ambiguous.\(^\text{36, 37}\) The following parameter values have been put forward as plausible by Eichengreen and Ghironi (1997): \(\phi = 40, \gamma = 9, \beta = .1\) and \(0 < \mu < 1\). For these parameter values, 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.\(^\text{38}\) 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.

Welfare impact of EMU

The equilibrium expected welfare loss for Germany and France \((i = G, F)\) is:

\[
E(L_i) = \left(\frac{\phi \beta^2 + \phi \gamma + 4 \gamma^2}{2 \phi}\right) \frac{\phi^2}{(\phi + k\phi\beta + 2k\gamma)^2}(kg_E^* + y_E)^2 + \\
+ \left[\frac{\phi \beta^2 + \phi \gamma + 4 \gamma^2}{2 \phi}\right] \left(\frac{\phi^2 + 2\phi H + 2H^2}{(\phi + \gamma + 2H)^2}\right) \phi (\phi + 4\gamma) \sigma^2. \tag{3.37}
\]

\(^{35}\)The is can be seen by comparing the first-order conditions of the Bundesbank \([\pi_G = -2\beta(y_G - y_E^*)]\) and the ECB \([\pi_E = -\beta(\frac{1}{2}(y_G + y_F) - y_E^*)]\).

\(^{36}\)The ambiguity can be seen as follows. On the one hand, French shocks are included in the euro area variables targeted by the ECB, whereas French shocks only had an indirect impact on Bundesbank policy (via the French authorities' policy response and the German-French exchange rate) before the start of EMU. On the other hand, intra-European monetary spillovers have been eliminated with the start of EMU. Therefore, the indirect impact of French shocks on Bundesbank policy may be larger than the direct impact on ECB policy, especially when the authorities find output stabilisation important, so that their policy response will be relatively strong and the resulting international spillovers large.

\(^{37}\)This comparison has some policy relevance, because the participation of the French franc in the exchange rate mechanism of the European Monetary System implies that French monetary policy was effectively determined by the German Bundesbank before the start of EMU.

\(^{38}\)If the authorities give a very high weight to output stabilisation \((\beta, \gamma \text{ very large})\), French shocks may have a larger impact on Bundesbank policy under floating rates than on ECB policy under EMU (see Tables C1 and C2). However, this possibility does not seem to be practically relevant.
The equilibrium expected welfare loss for the US is:

\[
E(L_s) = \frac{\phi \beta^2 + \phi \gamma + \gamma^2}{2\phi} \left\{ \frac{\phi^2}{(\phi + k\phi\beta + k\gamma)^2} (k\gamma + y_s)^2 + \frac{(\phi + \gamma)^2 + 2(\phi + \gamma + H)^2}{2(\phi + \gamma + 2H)^2} \right\}.
\]  

(3.38)

In order to facilitate an analytical comparison of 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 the credibility problem of the national central banks in Europe is alleviated, since 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.\(^{39}\)

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 shock components 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.\(^{40}\) 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, we look at US welfare. The part of the US welfare function associated with

\(^{39}\)The resulting lower seigniorage income leads to an increase of the output gap and government spending gap, but these effects are negligible, since seigniorage is relatively unimportant as a source of revenue in the euro area. It is easy to check that \(y_G^*, g_G^*, \) and \(t_G^*\) are unaffected by the start of EMU if \(\mu = 0.\)

\(^{40}\)If central banks mainly care for price stability and governments mainly care for attaining the desirable level of government spending (\(\beta\) small, \(\frac{1}{\sigma}\) small), the first effect (loss of policy instrument) dominates. However, if the authorities are more activist (\(\beta\) large, \(\frac{1}{\sigma}\) large), the second effect (higher credibility) is the dominating one.
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 trying to shift abroad the burden of adjustment to shocks. Thus, it follows that EMU is unambiguously welfare-improving for the United States.41

The exchange rate consequences of EMU

Another concern raised by EMU, not discussed in this article so far, is the exchange rate of the euro against the dollar. Despite the large size of the euro area economy, the exchange rate is still a major issue for politicians and central bankers in Europe.42 One reason is that the euro exchange rate may affect internal price stability in the euro area. Another factor, which is more of a political nature, is that the dollar-euro exchange rate is highly visible to the general public and is seen as an indicator of the success of monetary union in Europe.

The supply functions in this article stress the importance of international linkages between countries. Therefore, it is useful to see what EMU implies for the exchange rate in this model.

Because purchasing power parity is assumed to hold, combining equations (C1), (C2) and (C3) immediately yields the percentage change of the dollar-deutschmark exchange rate under floating rates:

\[
E_{GS} = \frac{2\phi\beta}{\phi + 2k(\phi\mu + \gamma)}(kg_E^* + y_E^*) - \frac{\phi\beta}{\phi + k(\phi\mu + \gamma)}(kg_S^* + y_S^*) + \beta \left\{ \frac{2\phi}{\phi + 6H}\varepsilon_G + \frac{\phi}{\phi + 6H} \right\} \left[ 3H \varepsilon_G + \varepsilon_F - \varepsilon_S \right].
\]

(3.39)

It seems realistic to assume that the government spending target in Europe is higher and that non-tax distortions are larger than in the US (i.e. \( g_E^* > g_S^* \) and \( y_E^* > y_S^* \)). Equation (3.39) indicates that this translates into an expected appreciation of the dollar.

41 The ambiguous welfare result of monetary unification for the monetary union itself is in line with the theory on optimal currency areas, initiated by Mundell (1961) and studied in general equilibrium models as of the early 1980s (Helpman, 1981). I am not aware of any articles that look at the welfare implications of a monetary union for third countries.

Thus, the distortions that cause the deviations from policy targets in Europe to be large relative to the US also cause an expected trend appreciation of the dollar.

Similarly, combining equations (C4), (C5) and (C6) immediately yields the change in the dollar-euro exchange rate under EMU:

\[ E_{ES} = \frac{\phi \beta}{\phi + k(\phi \mu \beta + 2\gamma)} (kg^*_E + y^*_E) - \frac{\phi \beta}{\phi + k(\phi \mu \beta + \gamma)} (kg^*_S + y^*_S) + \]

\[ -\frac{1}{2} \left( \frac{\beta}{\phi + \gamma + 2H} \right) [ (\phi - \gamma)(\varepsilon_G + \varepsilon_F) - 2(\phi + \gamma)\varepsilon_S]. \tag{3.40} \]

Again, a relatively high level of distortions in euro area member states leads to an expected upward drift of the dollar. However, the expected trend appreciation of the dollar will be more moderate under EMU than under floating rates. Having relatively large distortions in Europe still has a negative influence on the external value of the currency, but not as much as under floating rates. The intuition is as follows. The joint decision-making in the ECB Council implies that intra-European spillovers in monetary policy are internalised. This results in a lower inflation bias and a more moderate inflation response to shocks. Thus, the lower inflation bias under EMU (section 3.2.3) translates into a smaller dollar trend appreciation (i.e. enhances the relative strength of the euro).

The more moderate response of the ECB to euro area shocks means that the policy responses of the ECB and the Fed to a euro area shock is more alike than before. This implies that, under EMU, the dollar-euro exchange rate is less volatile after euro area shocks than it is under floating rates. By contrast, the more limited response of euro area inflation to US shocks implies that the policy responses of the ECB and the Fed diverge more strongly than before. This causes the dollar-euro exchange rate to respond more strongly to a negative supply shock in the US. The impact of EMU on the responsiveness of the exchange rate to worldwide shocks (defined as simultaneous shocks of equal size in Europe and the US) is ambiguous.\footnote{This confirms the results obtained in chapter 2 of this dissertation, which studied a three-country model without time-inconsistencies and without fiscal authorities, but including an explicit modeling of the exchange-rate mechanism of the European Monetary System.}

### 3.4 Conclusion

In this chapter, I have explored the possible welfare consequences of EMU. The model in this chapter 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.

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 no longer 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 inflation leads to lower seigniorage income), 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. The welfare impact of the loss of a policy instrument may or may not be dominated by improved policy incentives. The net welfare effect for the euro area is more positive (less negative) if structural distortions are large, if the variance of shocks is small and if policy-makers are more ‘activist’ (in the sense of having a high preference for output stability).

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 population size 1. Capital is assumed to be fixed. Therefore, output in each economy is a function of labour input only: $Y_i = L_i^\eta e^{\xi_i}$, $i = 1, \ldots, N$, where $Y_i$ is real output, $L_i$ is labour input and $\xi_i$ is a normally distributed, idiosyncratic shock with finite variance and expected value zero that hits country $i$ (i.e. $E\xi_i = 0$, $Var(\xi_i) = (\sigma^*)^2$, $i = 1, \ldots, N$). The constant $\eta$ 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. The representative firm maximises profits under the constraint that the size of the total workforce be pre-determined.

$$\max \prod_i = (1 - t_i)P_iY_i - W_iL_i + \sum_{j \neq i} X_{ij}[(1 - t_j)P_jY_j - W_jL_j].$$

s.t. $\sum_j L_j = L^*$,

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 ($X_{ij}P_j = P_i$), the Lagrangian function can be written as

$$\mathcal{L} = (1 - t_i)P_iY_i - W_iL_i + \sum_{j \neq i}[(1 - t_j)P_jY_j - P_i \frac{W_j}{P_j} L_j] + \lambda[\sum_j L_j - L^*].$$

Since each country has population size 1, there is no difference between output and output per capita here. This distinction will be made later in this appendix and also in the main text.

This particular set-up helps to highlight the cross-border impact of government policies. Intuitively, countries compete for being a favourable production site.
Chapter 3. The Welfare Implications of EMU

The first-order conditions are:

\[
\frac{\partial \mathcal{L}}{\partial L_i} = (1 - t_i)P_i \frac{\partial Y_i}{\partial L_i} - W_i + \lambda = 0, \quad (A3a)
\]

\[
\frac{\partial \mathcal{L}}{\partial L_j} = (1 - t_j)P_i \frac{\partial Y_j}{\partial L_j} - P_i \frac{W_j}{P_j} + \lambda = 0, \quad \forall j \neq i. \quad (A3b)
\]

Combining the first-order conditions (eliminating \(\lambda\)) and dividing both sides by \(P_i\) gives the following \(N - 1\) equations:

\[
(1 - t_i) \frac{\partial Y_i}{\partial L_i} - \frac{W_i}{P_i} = (1 - t_j) \frac{\partial Y_j}{\partial L_j} - \frac{W_j}{P_j}, \quad \forall j \neq i. \quad (A4)
\]

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 (A4) 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.\(^{46}\)

Rewrite:

\[
(1 - t_i)\eta L_i^{n-1}e^{\xi_i} - (1 - t_j)\eta L_j^{n-1}e^{\xi_j} = \frac{W_i}{P_i} - \frac{W_j}{P_j}, \quad \forall j \neq i. \quad (A5)
\]

For any two variables \(x, y\), the following approximation may be used around \((x_0, y_0) = (1, 1)\):\(^{47}\)

\[
x - y \approx \frac{x}{y} - 1. \quad (A6)
\]

When shocks are zero and when the tax rate is sufficiently small, each of the four additive terms in (A5) is equal to 1.\(^{48}\) Therefore, for small shocks, the approximation (A6) may be applied to both the left-hand side and right-hand side of (A5):

\[
\frac{(1 - t_i)\eta L_i^{n-1}e^{\xi_i}}{(1 - t_j)\eta L_j^{n-1}e^{\xi_j}} - 1 = \frac{W_i}{P_i} - 1, \quad \forall j \neq i. \quad (A7)
\]

\(^{46}\)Note that the assumption of decreasing returns to scale is essential here. Under constant returns to scale, firms might find it optimal to move all production to one country in response to shocks and policy surprises. The assumption of decreasing returns to scale ensures an interior solution.

\(^{47}\)Informal proof of (A6):

\[
f(x, y) \approx f(x_0, y_0) + (x - x_0) \frac{\partial}{\partial x} f(x_0, y_0) + (y - y_0) \frac{\partial}{\partial y} f(x_0, y_0) \Rightarrow
\]

\[
x \approx \frac{x_0}{y_0} + (x - x_0) \frac{1}{y_0} - (y - y_0) \frac{x_0}{(y_0)^2} = 1 + (x - 1) - (y - 1) = x - y + 1
\]

(Q.E.D.)

\(^{48}\)This assertion will be confirmed in steps 1 and 2 of the game. It follows directly from equations (A20) and (A23), after taking anti-logs. Also recall that countries have population size one, so that \(L_i\) and \(L_j\) are close to one.
Eliminate corresponding terms and take logs:

\[
\log(1 - t_j) + (\eta - 1)l_j + \xi_j - \log(1 - t_i) - (\eta - 1)l_i - \xi_i
\]

\[
= (w_j - p_j) - (w_i - p_i), \quad \forall j \neq i. \tag{A8}
\]

Add all \(N - 1\) equations

\[
\sum_{j \neq i} [\log(1 - t_j) + (\eta - 1)l_j + \xi_j] - (N - 1)[\log(1 - t_i) + (\eta - 1)l_i + \xi_i]
\]

\[
= \sum_{j \neq i} (w_j - p_j) - (N - 1)(w_i - p_i), \quad i = 1, \ldots, N. \tag{A9}
\]

Note that for small deviations from equilibrium, the following approximation may be used:\textsuperscript{49}

\[
\sum_j l_j = \sum_j l_j^*. \tag{A10}
\]

For the moment, assume that

\[
l_j^* = \left(\frac{1}{1 - \eta}\right)(-t_j^* + \log \eta).
\]

The validity of this equation will be confirmed in step 2 of the game (see equation \(A21\) below). Using this assumption, \((A10)\) can be rewritten as

\[
\sum_{j \neq i} l_j = -l_i + l_i^* + \sum_{j \neq i} l_j^* =
\]

\[
= -l_i + \frac{1}{1 - \eta}(-t_i^* + \log \eta) + \sum_{j \neq i} \frac{1}{1 - \eta}(-t_j^* + \log \eta). \tag{A11}
\]

\textsuperscript{49}Informal proof of \((A10)\): Let \(L_j^*\) denote the amount of labour which was initially contracted in country \(j\). Then

\[
l_j - l_j^* = \log\left(\frac{L_j}{L_j^*}\right) = \log(1 + \frac{L_j - L_j^*}{L_j^*}) \approx \frac{L_j - L_j^*}{L_j^*}, \quad j = 1, \ldots, N,
\]

where the last equality follows from the fact that \(L_j - L_j^*\) is close to zero for small deviations from equilibrium. Then, adding all \(N\) equations:

\[
\sum_j (l_j - l_j^*) = \sum_j \left(\frac{L_j - L_j^*}{L_j^*}\right) = \frac{1}{L_j^*} [\sum_j L_j - L^*] = 0,
\]

where the last equality follows directly from the constraint that the total workforce is pre-determined. (Q.E.D.)
Substitute this result into \((A9)\) and note that \(\log(1 - t_i)\) can be approximated by \(-t_i\):\(^{50}\)

\[
N(1 - \eta)l_i = N(-t^*_i + \log \eta) - (N - 1)(w_i - p_i + t_i - t^*_i) + \\
\quad + \sum_{j \neq i}(w_j - p_j + t_j - t^*_j) + (N - 1)\xi_i - \sum_{j \neq i}\xi_j, \tag{A12}
\]

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 \(\frac{N}{2N - 1}\log(\frac{N}{2N - 1})\). Then:

\[
y_i = -\left(\frac{N}{N - 1}\right)t^*_i - (w_i - p_i + t_i - t^*_i) + \\
\quad + \frac{1}{N - 1}\sum_{j \neq i}(w_j - p_j + t_j - t^*_j) + \varepsilon_i, \quad \forall i, \tag{A13}
\]

where \(\varepsilon_i\) is a random shock with expectation zero and finite variance:

\[
\varepsilon_i = 2\xi_i - \frac{1}{N - 1}\sum_{j \neq i}\xi_j, \quad i = 1, \ldots, N.
\]

It is easy to check that \(E\varepsilon_i = E\varepsilon_j = 0\), \(Var(\varepsilon_i) = Var(\varepsilon_j) = (\frac{4N - 3}{N - 1})(\sigma^*)^2\) and \(\varepsilon_i > \varepsilon_j \iff \xi_i > \xi_j\).

**Step 4:** Derivation of optimal monetary and fiscal policies. See the main text (Section 2) for this step.

**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 \(i\)):\(^{51}\)

\[
\text{Max}_{(L_1, \ldots, L_N)} E \prod_i = E\{(1 - t_i)P_iY_i - W_iL^*_i + \\
\quad + \sum_{j \neq i}X_{ij}\{(1 - t_j)P_jY_j - W_jL^*_j\}\}. \tag{A14}
\]

At this stage, there is no constraint on labour. Shocks \(\xi_i\) are uncorrelated. Therefore, maximising expected worldwide profits is equivalent to maximising expected profits in each country separately:

\[
\text{Max}_{(L^*_i)} E \prod_i = E\{(1 - t_i)P_iY_i - W_iL^*_i\} \\
\quad = E\{(1 - t_i)P_i(L^*_i)^a\xi_i - W_iL^*_i\}, \quad i = 1, \ldots, N. \tag{A15}
\]

\(^{50}\)This approximation is somewhat imprecise when the tax rate is a substantial share of output, but it is common in the literature. See, for instance, Beetsma and Bovenberg (1999b).

\(^{51}\)I could have assumed that the amount of labour \(L^*_i\) were exogenously given instead. In that case a symmetric increase in equilibrium (distortionary) taxes would have no impact on output. The current set-up gives the model the desirable property that a world-wide increase in equilibrium tax rates leads to a decline in world output.
The firm's expectations are formed and the $L_i^*$ are chosen before shocks ($\xi_i$) 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, (A15) can be rewritten as

$$\text{Max}_{L_i^*} \ E \prod_i = (L_i^*)^n E[(1 - t_i)P_i e^{\xi_i}] - W_i L_i^*, \quad i = 1, ..., N. \quad (A16)$$

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

$$\frac{\partial E \prod_i}{\partial L_i^*} = \frac{\partial ((L_i^*)^n E[(1 - t_i)P_i e^{\xi_i}] - W_i L_i^*)}{\partial L_i^*} = 0, \quad i = 1, ..., N, \quad (A17)$$

which can be rewritten as:

$$\eta (L_i^*)^{n-1} E \{(1 - t_i)P_i e^{\xi_i}\} = W_i. \quad (A18)$$

Take logs and note that, for small shocks, $\log E \{..\} \approx E \log \{..\}$:

$$\log \eta + (\eta - 1) l_i^* + E [\log(1 - t_i) + p_i + \xi_i] = w_i. \quad (A19)$$

Approximate $\log(1 - t_i)$ by $-t_i$ and rearrange:

$$\log \eta + (\eta - 1) l_i^* - t_i^* = w_i - p_i^*, \quad i = 1, ..., N. \quad (A20)$$

Equation (A20) is the familiar condition that the expected after tax marginal product of labour must be equal to the expected real wage.$^{52}$ The right hand side is equal to zero, because it is optimal for workers to choose $w_i = p_i^*$ (as will be shown below). Therefore, equation (A20) simplifies to:

$$l_i^* = \left(\frac{1}{1 - \eta}\right)(-t_i^* + \log \eta), \quad i = 1, ..., N. \quad (A21)$$

where $l_i^*$ denotes the optimal amount of labour to be initially hired in country $i$. Note that $l_i^*$ is a function of the expected tax rate and the marginal productivity of labour.$^{53}$

**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)

$$\text{Min}_{W_i} \ E(W_i - P_i)^2, \quad i = 1, ..., N. \quad (A22)$$

$^{52}$This is easier to see after taking anti-logs: $(1 - l_i^*)\eta (L_i^*)^{n-1} = \frac{W_i}{P_i}$.

$^{53}$Recall that we have assumed decreasing marginal returns to scale ($\eta < 1$). Under constant returns to scale, the variables $l_i^*$ would be indetermined, since it is costless to shift workers from one country to another at a later stage. Decreasing marginal returns to scale impose an implicit cost on shifting workers from one country to another, as will be explained later in this appendix.
It is directly clear that it is optimal for workers to choose \( W_i = P_i^e \), which (after taking logs) yields

\[
w_i = p_i^e, \quad i = 1, \ldots, N.
\]  

(A23)

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 (A13).

A.2 Output per capita in two countries of equal size

Next, the formulas for output per capita can be derived for a world consisting of two countries of equal size, where size may differ from 1. Following the procedure by Martin (1997) yields the following equations, which turn out to be equal to the expressions which would have been obtained by simply setting \( N = 2 \) in (A13)

\[
y_1 = -2t_1 + (w_1 - p_1 + t_1 - t_1^e) + (w_2 - p_2 + t_2 - t_2^e) + \varepsilon_1.
\]  

(A24)

\[
y_2 = -2t_2 + (w_1 - p_1 + t_1 - t_1^e) - (w_2 - p_2 + t_2 - t_2^e) + \varepsilon_2.
\]  

(A25)

The procedure is not written out in full because it is similar to (but simpler than) the case below.

A.3 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 \( \eta_i \) have expected value zero and variance \( \sigma^2, i = 1, \ldots, N. \) 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{align*}
y_1 &= \frac{1}{n_1} \sum_{i \leq i_1} \left[ \frac{N}{N-1} t_i^e - (w_i - p_i + t_i - t_1^e) \right] + \\
&+ \frac{1}{N-1} \sum_{j \neq i} (w_j - p_j + t_j - t_1^e) + \eta_i \\
&= \frac{1}{n_1} \sum_{i \leq i_1} \left[ \frac{N}{N-1} t_i^e - (w_i - p_i + t_i - t_1^e) \right] + \\
&+ \frac{1}{N-1} \left[ (n_1 - 1)(w_1 - p_1 + t_1 - t_1^e) + n_2(w_2 - p_2 + t_2 - t_2^e) + \\
&+ n_3(w_3 - p_3 + t_3 - t_3^e) \right] + \eta_i \\
&= -\left( \frac{N}{N-1} \right) t_1^e - \left( \frac{N-n_1}{N-1} \right)(w_1 - p_1 + t_1 - t_1^e) + \\
&+ \frac{n_2}{N-1} (w_2 - p_2 + t_2 - t_2^e) + \\
&+ \frac{n_3}{N-1} (w_3 - p_3 + t_3 - t_3^e) + \epsilon_1. \quad (A26)
\end{align*}

Analogously:

\begin{align*}
y_2 &= -\left( \frac{N}{N-1} \right) t_2^e + \frac{n_1}{N-1} (w_1 - p_1 + t_1 - t_1^e) + \\
&+ \left( \frac{N-n_2}{N-1} \right)(w_2 - p_2 + t_2 - t_2^e) + \\
&+ \frac{n_3}{N-1} (w_3 - p_3 + t_3 - t_3^e) + \epsilon_2. \quad (A27)
\end{align*}

\begin{align*}
y_3 &= -\left( \frac{N}{N-1} \right) t_3^e + \frac{n_1}{N-1} (w_1 - p_1 + t_1 - t_1^e) + \\
&+ \frac{n_2}{N-1} (w_2 - p_2 + t_2 - t_2^e) + \\
&+ \left( \frac{N-n_3}{N-1} \right)(w_3 - p_3 + t_3 - t_3^e) + \epsilon_3. \quad (A28)
\end{align*}

Normalise: \( n_1 = n_2 = \frac{1}{2}, n_3 = 1 \). Then:

\begin{align*}
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) + \\
&+ (w_3 - p_3 + t_3 - t_3^e) + \epsilon_1, \quad (A29)
\end{align*}

\begin{align*}
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) + \\
&+ (w_3 - p_3 + t_3 - t_3^e) + \epsilon_2, \quad (A30)
\end{align*}
\[ y_3 = -2t_3^2 + \frac{1}{2}(w_1 - p_1 + t_1 - t_1^2) + \frac{1}{2}(w_2 - p_2 + t_2 - t_2^2) + (w_3 - p_3 + t_3 - t_3^2) + \varepsilon_3. \]  

(A31)

The two-country model (A24)-(A25) and the three-country model (A29)-(A31) share the following characteristics. First, output per capita is negatively correlated with the expected tax rate, the real wage rate (=money surprise) and a tax surprise in the home country. Secondly, output per capita is positively correlated with the foreign real wage and the foreign tax surprise. This implies that there are international spillovers present in the model. Third, the 'activity shift' terms do not affect world output per capita. Fourth, output per capita is more responsive to the expected tax rate than to a tax surprise. The reason is that the total worldwide number of workers is fixed before tax surprises materialise. This implies that a surprise tax increase will not only induce a reduction in the amount of labour employed in the home country, but must be accompanied by an increase in the amount of labour employed in the foreign country. Decreasing returns to scale (in combination with the fact that we start from equilibrium, where the after tax marginal product of labour is equal to the real wage rate) imply that the additional output produced in the foreign country must be sold at a loss. This imposes an implicit cost on moving workers and will induce the firm to reduce output in the home country by less than would otherwise have been done. Thus, fixing the worldwide number of workers reduces the responsiveness of output to the tax rate.

One new characteristic appears in (A29)-(A31): output in a small country is more responsive to a domestic policy surprise than output in a large country. This can be most easily seen in case of one small country (of size one) and one large country (consisting of \( N - 1 \) subregions of size one). A tax increase in the small country implies that the firm wants to reduce the amount of labour in the small country by, say, \( x \). Since the total number of workers is fixed, this implies that the amount of labour in the foreign (=large) country must be increased by \( x \). The additional output produced in the foreign country is sold at a loss, making it optimal to shift a smaller amount of workers \( x'(< x) \). The same tax increase in the large country implies that the firm wants to reduce the amount of labour employed in each of the subregions by \( x \). This requires an increase in the amount of labour in the foreign (=small) country by \( (N - 1)x \). Again, the additional output is sold at a loss. The additional output (and the resulting loss) in the foreign country is larger in this case, so that it will be optimal to shift a smaller amount of workers \( x''(< x' < x) \).\(^{54} \) Thus, moving workers in response to a domestic policy surprise is more

\(^{54}\) Decreasing returns to scale work are not essential in explaining the relatively large output response
costly if the foreign country is relatively small, i.e. if the home country is relatively large. This explains that output is more responsive to domestic policy surprises in a small country.

I have adjusted the weights in the three-country model in the main text [equations (3.14)-(3.16)] 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 above-mentioned characteristics. 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 $k > 1$). Thus, the supply per capita curves for the two-country case in the main text [equations (3.1)-(3.2)] are slightly different from equations (A24)-(A25). These adjustments do not qualitatively affect the conclusions of this chapter.

B Derivation of solutions: two countries

In this appendix, the two-country model given by equations (3.3)-(3.7) in the main text is solved under different assumptions with respect to commitment technology.

The deterministic and stochastic parts of the model can be solved separately. The deterministic part is found by imposing rational expectations and zero shocks. The expected values of all variables can be expressed as a function of the structural distortions. Consecutively, the model can be solved in deviations from the expected values. The deviation of the expected value of all variables can be expressed as a function of the stochastic shocks.

B.1 Deterministic part of the model

In the deterministic part of the model, there are no spillovers between countries. Therefore, full commitment and a single policymaker in each country give the first-best solution. Starting from this situation, the following elements are introduced one by one: central bank independence, a credibility problem of the fiscal authorities, a credibility problem of the monetary authorities.

in a small country, and in fact work against it: decreasing returns to scale imply that increasing the amount of labour by $x/(N - 1)$ in the $N - 1$ subregions of the large country has a larger output effect than increasing the amount of labour by $x$ in the small country (but not larger than increasing the amount of labour in the small country by $(N - 1)x$, as required).
Full commitment, single policy maker in each country

It is assumed that policy makers can commit with respect to their policy instruments. There is a single policy maker in each country, who sets both the tax rate and the inflation rate. The two policy makers have the loss function in equation (3.5) in the main text. They play Nash against each other.

The equilibrium with full commitment can be computed by imposing the requirements that $E(t_i) = t_i^*$ and $E(\pi_i) = \pi_i^*$ before taking first-order conditions. Thus, policy makers take into account that in equilibrium, no unexpected policy changes are possible (see Alesina and Tabellini, 1987).

The deterministic part of the solution can be found as follows. Take expectations of the supply curves (3.3)-(3.4) and the budget constraints (3.6) in the main text and impose the requirement of rational expectations. Substitute the resulting equations into the loss function of the European government and minimise with respect to the (expected) tax rate and the (expected) inflation rate. This gives the first-order conditions for the European government:

$$\phi(g_E^E - g_E^E) = k\gamma(y_E^E - y_E^E)$$

$$\pi_E^* = -\phi\mu(g_E^E - g_E^E).$$

(B1a)

(B1b)

Combining (B1a)-(B1b) with equations (3.3)-(3.4) and (3.6) yields the solution in terms of the determinants of welfare $(y_E^E - y_E^E, g_E^E - g_E^E, \mu\pi_E)$ and the other variables in equation (3.8) in the main text. The deterministic components of the reduced-form solution are shown in Table B1. Since the single policy maker takes into account the role of seigniorage as a source of government revenue, optimal taxation implies a positive inflation rate (see equation B1b).\textsuperscript{55}

Full commitment, decentralised policy making

The responsibility for monetary policy is delegated to an independent central bank.\textsuperscript{56}

There are now four policy makers, who play Nash against each other. The loss functions are given by equations (3.5) and (3.7) in the main text.

The solution of the game follows the steps of the previous case, with one exception. Central banks no longer take into account the impact of seigniorage on the government

\textsuperscript{55}Note that $g_E^E - g_E^E$ and $y_E^E - y_E^E$ are always negative, as the presence of distortions ensures that the target level (zero) will not be attained in equilibrium. Therefore, the right-hand side of equation B1b is positive, which implies that the left-hand side must also be positive.

\textsuperscript{56}This exercise is purely for illustration purposes, so we are not concerned with the optimality of such a decision in the absence of a credibility problem.
budget. The first-order conditions for the euro area authorities are:

\[
\phi(g_E^r - g_E) = k\gamma(y_E^r - y_E),
\]

\[
\pi_E^r = 0.
\]

Combining (B2a)-(B2b) with equations (3.3)-(3.4) and (3.6) in the main text yields the deterministic components of the reduced-form solution, as shown in Table B1. The optimal tradeoff between spending stabilization and output stabilization for the fiscal authority is identical to the trade-off under centralised policy making. However, there is no longer a trade-off between inflation and output in equilibrium. Under decentralised policy making, the central bank does not take into account this role of seigniorage. Under full commitment, the central bank cannot affect output in equilibrium. Hence, in the absence of shocks, it is optimal for the central bank to set inflation equal to its target rate (zero). Wage setters know this when forming expectations. Therefore, expected inflation is zero. Note that the reduced-form solution under decentralised policymaking equals the solution under centralised policymaking when \( \mu = 0 \).

Monetary commitment, fiscal discretion, decentralised policy making

The fiscal authorities are unable to commit. Monetary policy is determined by independent central banks who can commit.\(^{57}\)

The deterministic part is solved as in the previous case, with one exception. The equilibrium with monetary commitment is computed by imposing the requirement that \( E(\pi_t) = \pi_t^r \) before taking first-order conditions, whereas \( E(t_t) = t_t^r \) is imposed afterwards. The resulting conditions for the euro area authorities are:

\[
\phi(g_E^r - g_E) = \gamma(y_E^r - y_E^r),
\]

\[
\pi_E^r = 0.
\]

The deterministic components of the reduced-form solution are shown in Table B1. As before, the fiscal authorities face a tradeoff between cutting taxes (in order to stimulate domestic output) and raising taxes (in order to enable additional government spending). After firms have invested in labour, the become less responsive to the tax rate. This causes the optimal tradeoff for the fiscal authorities to shift in favour of a higher tax rate. Therefore, fiscal authorities would like to promise a low tax rate and hike taxes after firms have invested in human capital. Firms are aware of this possibility and adjust

\(^{57}\)If central banks can commit, whereas fiscal authorities cannot, it would be appropriate to consider central banks as Stackelberg leaders against the fiscal authorities. Since this exercise is purely for illustrational purposes, I will disregard this complication.
tax expectations accordingly. The fact that the fiscal authorities can no longer commit results in an unambiguously higher equilibrium tax rate than under full commitment, as can be easily verified from Table 1.

**Table B1 Solution to two-country game (deterministic parts)**

<table>
<thead>
<tr>
<th>variable</th>
<th>full commitment, single policy maker in each country</th>
<th>full commitment, independent central bank</th>
</tr>
</thead>
<tbody>
<tr>
<td>$y_E - y_E$</td>
<td>$\frac{\phi}{\phi + k^2 (\phi \mu^2 + \gamma)} [g_E^* + y_E^* + (k - 1)g_E^*]$</td>
<td>$\frac{\phi}{\phi + k^2 \gamma} [g_E^* + y_E^* + (k - 1)g_E^*]$</td>
</tr>
<tr>
<td>$g_E - g_E$</td>
<td>$\frac{k^2 \gamma}{\phi + k^2 (\phi \mu^2 + \gamma)} [g_E^* + y_E^* - (\frac{k-1}{k})y_E^*]$</td>
<td>$\frac{k^2 \gamma}{\phi + k^2 \gamma} [g_E^* + y_E^* - (\frac{k-1}{k})y_E^*]$</td>
</tr>
<tr>
<td>$\mu \pi_E$</td>
<td>$\frac{k^2 \phi \mu^2}{\phi + k^2 (\phi \mu^2 + \gamma)} [g_E^* + y_E^* - (\frac{k-1}{k})y_E^*]$</td>
<td>0</td>
</tr>
<tr>
<td>$-(k-1)t_E$</td>
<td>$\frac{k^2 \phi \mu^2 + \gamma}{\phi + k^2 (\phi \mu^2 + \gamma)} (\frac{k-1}{k})y_E^* + \frac{\phi}{\phi + k^2 (\phi \mu^2 + \gamma)} (k - 1)g_E^*$</td>
<td>$\frac{k^2 \phi \mu^2 + \gamma}{\phi + k^2 \gamma} (\frac{k-1}{k})y_E^* + \frac{\phi}{\phi + k^2 \gamma} (k - 1)g_E^*$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>variable</th>
<th>monetary commitment, fiscal discretion, independent central bank</th>
<th>monetary discretion, fiscal discretion, independent central bank</th>
</tr>
</thead>
<tbody>
<tr>
<td>$y_E^* - y_E$</td>
<td>$\frac{\phi}{\phi + k^2 (\phi \mu^2 + \gamma)} [g_E^* + y_E^* + (k - 1)g_E^*]$</td>
<td>$\frac{\phi}{\phi + k^2 \gamma} [g_E^* + y_E^* + (k - 1)g_E^*]$</td>
</tr>
<tr>
<td>$g_E^* - g_E$</td>
<td>$\frac{k^2 \gamma}{\phi + k^2 (\phi \mu^2 + \gamma)} [g_E^* + y_E^* - (\frac{k-1}{k})y_E^*]$</td>
<td>$\frac{k^2 \gamma}{\phi + k^2 \gamma} [g_E^* + y_E^* - (\frac{k-1}{k})y_E^*]$</td>
</tr>
<tr>
<td>$\mu \pi_E$</td>
<td>0</td>
<td>$\frac{k^2 \phi \mu^3 \gamma}{\phi + k^2 (\phi \mu^3 + \gamma)} [g_E^* + y_E^* - (\frac{k-1}{k})y_E^*]$</td>
</tr>
<tr>
<td>$-(k-1)t_E$</td>
<td>$\frac{k^2 \phi \mu^3 + \gamma}{\phi + k^2 (\phi \mu^3 + \gamma)} (\frac{k-1}{k})y_E^* + \frac{\phi}{\phi + k^2 (\phi \mu^3 + \gamma)} (k - 1)g_E^*$</td>
<td>$\frac{k^2 \phi \mu^3 + \gamma}{\phi + k^2 \gamma} (\frac{k-1}{k})y_E^* + \frac{\phi}{\phi + k^2 \gamma} (k - 1)g_E^*$</td>
</tr>
</tbody>
</table>

Full discretion, decentralised policy making

Neither the fiscal authorities, nor the monetary authorities are able to commit. The equilibrium with full discretion is computed by imposing the requirement that $E(t_i) = t_i^*$.
and $E(\pi_t) = \pi_t^*$ after taking first-order conditions. Therefore, the deterministic and stochastic parts of the model can be solved simultaneously. The resulting conditions are:

\[ \pi_E^* = -\beta(y^*_E - y_E^*), \tag{B4a} \]
\[ \phi(y^*_E - y_E^*) = \gamma(y^*_E - y_E^*). \tag{B4b} \]

Combining (B4a)-(B4b) with equations (3.3)-(3.4) and (3.6) in the main text yields the deterministic components of the solution, as shown in Table B1. These results are repeated in Table 1 in the main text.

Compared to the previous case, the fact that monetary authorities cannot commit re-introduces a positive inflation bias. The intuition is that workers are fully locked in after setting nominal wages. Therefore, central banks can stimulate output by promising a low inflation rate and creating inflation after wages are set. Workers anticipate this in equilibrium, so that discretion has an optimal upward effect on their inflation expectations.\footnote{Observe that this inflation bias is not necessarily welfare-reducing, as it helps to offset the loss from the fact that the independent central bank ignores the contribution of seigniorage revenue to the government budget and may therefore set inflation sub-optimally low.}

### B.2 Stochastic part of the model

Next, the model will be solved in deviations from the expected values. The deviations from the expected values are a function of the stochastic shocks. The response of the authorities to stochastic shocks is not affected by the (im)possibility to commit. However, there are spillovers between countries (shifts of activity in response to surprise inflation or surprise tax cuts) in the stochastic part of the model. The stochastic part of the solution is only affected by the degree of policy (de)centralisation.

I have calculated the outcome with a single world policymaker. The outcome is characterised by the absence of beggar-thy-neighbour policies. Policy instruments only respond to the difference between shocks. The exact formulas do not provide additional insight and are not reported. The results under a single policymaker in each country and when monetary policy is delegated to independent central banks are discussed below.

**Single policymaker in each country**

The stochastic part of the solution is found as follows. First, substitute the supply curve and the government budget constraint into the loss function of the European government
and minimise with respect to the euro area tax rate and euro area inflation. This gives the first-order conditions for the European government:

\[
\begin{align*}
\phi(g_E - g_E^*) &= \gamma(y_E - y_E^*), \\
\pi_E &= -\gamma(y_E - y_E^*) - \phi\mu(g_E - g_E^*).
\end{align*}
\] (B5a)

(B5b)

Take expectations on both sides and subtract the resulting equations from (B5a)-(B5b). Then substitute (B5a) into (B5b) in order to simplify. This results in

\[
\begin{align*}
\phi(g_E - g_E^*) &= \gamma(y_E - y_E^*), \\
\pi_E - \pi_E^* &= -\gamma(1 + \mu)(y_E - y_E^*).
\end{align*}
\] (B6a)

(B6b)

Combining these equations with their US counterparts and with equations (3.3)-(3.4) and (3.6) yields the solution in terms of the determinants of welfare and the other variables in equation (3.8) in the main text. The stochastic components of the solution are shown in Table B2.

**Independent central bank**

The derivation of the stochastic part of the solution follows the steps of the previous case, except for the fact that central banks no longer take into account the impact of seigniorage on the government budget. The first-order conditions are:

\[
\begin{align*}
\phi(g_E - g_E^*) &= \gamma(y_E - y_E^*), \\
\pi_E &= -\beta(y_E - y_E^*). 
\end{align*}
\] (B7a)

(B7b)

Take expectations on both sides of these equations and subtract the resulting equations from (B7a)-(B7b). This results in

\[
\begin{align*}
\phi(g_E - g_E^*) &= \gamma(y_E - y_E^*), \\
\pi_E - \pi_E^* &= -\beta(y_E - y_E^*).
\end{align*}
\] (B8a)

(B8b)

The stochastic components of the reduced-form solution are shown in Table B2 (and repeated in Table 1 in the main text). The results under decentralised policy making are equal to those under centralised policy making after substituting $\gamma(1 + \mu) = \beta$. The fact that an independent central bank does not take into account the role of seigniorage as a source of government revenue is equivalent to setting $\mu = 0$. Moreover, by making the central bank independent, it follows its own preferences ($\beta$) rather than those of the government ($\gamma$). If the central bank is conservative, then the inflation response to a shock will be unambiguously more moderate under central bank independence.59

59 A conservative central bank has a relatively strong preference for low inflation (i.e. $\beta < \gamma$). See, for instance, DeBelle (1996).
### Table B2  Solution to two-country game (stochastic parts)

<table>
<thead>
<tr>
<th>variable</th>
<th>single policymaker in each country</th>
<th>independent central bank</th>
</tr>
</thead>
<tbody>
<tr>
<td>$y_E^* - y_E$</td>
<td>$- (A \varepsilon_E + B \varepsilon_S)$</td>
<td>$- (K \varepsilon_E + L \varepsilon_S)$</td>
</tr>
<tr>
<td>$g_E^* - g_E$</td>
<td>$- \frac{2}{\phi} (A \varepsilon_E + B \varepsilon_S)$</td>
<td>$- \frac{2}{\phi} (K \varepsilon_E + L \varepsilon_S)$</td>
</tr>
<tr>
<td>$\mu \pi_E$</td>
<td>$- \mu \gamma (1 + \mu) (A \varepsilon_E + B \varepsilon_S)$</td>
<td>$- \mu \beta (K \varepsilon_E + L \varepsilon_S)$</td>
</tr>
<tr>
<td>$\pi_E - \pi_E^*$</td>
<td>$- \gamma (1 + \mu) (A \varepsilon_E + B \varepsilon_S)$</td>
<td>$- \beta (K \varepsilon_E + L \varepsilon_S)$</td>
</tr>
<tr>
<td>$-(\pi_S - \pi_S^*)$</td>
<td>$\gamma (1 + \mu) (B \varepsilon_E + A \varepsilon_S)$</td>
<td>$\beta (L \varepsilon_E + K \varepsilon_S)$</td>
</tr>
<tr>
<td>$t_S - t_S^*$</td>
<td>$\frac{\omega \mu (1 + \mu) + \gamma}{\phi} (B \varepsilon_E + A \varepsilon_S)$</td>
<td>$\frac{\omega \mu (1 + \mu) + \gamma}{\phi} (L \varepsilon_E + K \varepsilon_S)$</td>
</tr>
</tbody>
</table>

where

$$A = \frac{\phi + G}{\phi + 2G}; \quad B = \frac{G}{\phi + 2G}; \quad \text{with } G = \phi \gamma (1 + \mu)^2 + \gamma$$

and

$$K = \frac{\phi + H}{\phi + 2H}; \quad L = \frac{H}{\phi + 2H}; \quad \text{with } H = \phi \beta (1 + \mu) + \gamma.$$

### C  Derivation of solutions: three countries

In this appendix, the three-country version of the model is solved under the assumptions of floating rates and EMU in Europe, respectively.

#### Three countries, floating rates

Policy making is decentralised. Policy-makers are unable to commit. The derivation of the solution is analogous to the two-country case. The expected inflation and tax rates in Europe (under the assumption of rational expectations) are:
The expected inflation and tax rates in the US are the same as in the two-country case.

The response of German inflation and tax rates (in deviation from their expected value) to shocks is:

\[
\pi_i^e = \frac{2\phi \beta}{\phi + 2k(\phi \mu \beta + \gamma)} [kg_i^* + y_i^*], \quad i = G, F. \tag{C1a}
\]

\[
t_i^e = \frac{1}{\phi + 2k(\phi \mu \beta + \gamma)} [\phi g_i^* - 2(\phi \mu \beta + \gamma)y_i^*], \quad i = G, F. \tag{C1b}
\]

The solution for the French inflation and tax rates follow directly by symmetry. The response of inflation and tax rates in the United States is:

\[
\pi_S^d = -\left[ \frac{2\phi \beta}{\phi + 6H} \right] \varepsilon_G - \left[ \frac{2\beta H}{\phi + 3H} \right] \frac{2\phi + 3H}{\phi + 6H} (\varepsilon_G + \varepsilon_F + \varepsilon_s). \tag{C2a}
\]

\[
t_S^d = \left[ \frac{2(\phi \mu \beta + \gamma)}{\phi + 6H} \right] \varepsilon_G + \left[ \frac{2(\phi \mu \beta + \gamma)H}{\phi(\phi + 3H)} \right] \frac{2\phi + 3H}{\phi + 6H} (\varepsilon_G + \varepsilon_F + \varepsilon_s). \tag{C2b}
\]

The deterministic components of the variables in Table C1 are functions of the exogenous distortions \( g_E^* \) and \( y_E^* \). They add up to \( g_E^* + y_E^* \), as required by equation (3.22) in the main text. The stochastic components of all German variables in Table C1 are functions of the composite shock \( \varepsilon_{G, \text{float}}^{\text{comp}} \). The stochastic components of the variables in Table C1 add up to \(-\varepsilon_G\), as required.
Table C1  Solution to three-country game under floating rates

<table>
<thead>
<tr>
<th>variable</th>
<th>deterministic component</th>
<th>stochastic component</th>
</tr>
</thead>
<tbody>
<tr>
<td>( y_E^* - y_G )</td>
<td>( \frac{\phi}{\phi + 2k(\varphi \mu \beta + \gamma)} \left[ g_E^* + y_E^* + (k - 1)g_E^* \right] )</td>
<td>(-\varepsilon_{G, \text{float}}^{\text{comp.}})</td>
</tr>
<tr>
<td>( g_E^* - g_G )</td>
<td>( \frac{2k\gamma}{\phi + 2k(\varphi \mu \beta + \gamma)} \left[ g_E^* + y_E^* - \left( \frac{k-1}{k} \right) y_E^* \right] )</td>
<td>(-\frac{2\mu}{\phi} \varepsilon_{G, \text{float}}^{\text{comp.}})</td>
</tr>
<tr>
<td>( \mu \pi_G )</td>
<td>( \frac{2k\varphi \mu \beta}{\phi + 2k(\varphi \mu \beta + \gamma)} \left[ g_E^* + y_E^* - \left( \frac{k-1}{k} \right) y_E^* \right] )</td>
<td>(-2\mu\beta \varepsilon_{G, \text{float}}^{\text{comp.}})</td>
</tr>
<tr>
<td>(-(k - 1)t_G^c)</td>
<td>( \frac{2k\varphi \mu \beta + 2k\gamma}{\phi + 2k(\varphi \mu \beta + \gamma)} \left( \frac{k-1}{k} \right) y_E^* + \frac{\phi}{\phi + 2k(\varphi \mu \beta + \gamma)} (k - 1)g_E^* )</td>
<td>0</td>
</tr>
<tr>
<td>( 2(\pi_G - \pi_G^e) )</td>
<td>0</td>
<td>(-4\beta \varepsilon_{G, \text{float}}^{\text{comp.}})</td>
</tr>
<tr>
<td>(-(t_G - t_G^e))</td>
<td>0</td>
<td>(-\left( 2\mu \beta + \frac{2\gamma}{\phi} \right) \varepsilon_{G, \text{float}}^{\text{comp.}})</td>
</tr>
<tr>
<td>(-(\pi_F - \pi_F^e))</td>
<td>0</td>
<td>(2\beta \varepsilon_{F, \text{float}}^{\text{comp.}})</td>
</tr>
<tr>
<td>( t_F - t_F^e )</td>
<td>0</td>
<td>(\left( 2\mu \beta + \frac{2\gamma}{\phi} \right) \varepsilon_{F, \text{float}}^{\text{comp.}})</td>
</tr>
<tr>
<td>(-(\pi_S - \pi_S^e))</td>
<td>0</td>
<td>(\beta \varepsilon_{S, \text{float}}^{\text{comp.}})</td>
</tr>
<tr>
<td>( t_S - t_S^e )</td>
<td>0</td>
<td>(\left( \mu \beta + \frac{2\gamma}{3} \right) \varepsilon_{S, \text{float}}^{\text{comp.}})</td>
</tr>
</tbody>
</table>

where

\[
\varepsilon_{G, \text{float}}^{\text{comp.}} = \frac{\phi}{\phi + 6H} \varepsilon_G + \frac{H}{\phi + 6H} \left[ \frac{2\phi + 3H}{\phi + 6H} (\varepsilon_G + \varepsilon_F) + \varepsilon_S \right].
\] (C4a)

\[
\varepsilon_{F, \text{float}}^{\text{comp.}} = \frac{\phi}{\phi + 6H} \varepsilon_F + \frac{H}{\phi + 6H} \left[ \frac{2\phi + 3H}{\phi + 6H} (\varepsilon_G + \varepsilon_F) + \varepsilon_S \right].
\] (C4b)

\[
\varepsilon_{S, \text{float}}^{\text{comp.}} = \frac{H}{\phi + 3H} (\varepsilon_G + \varepsilon_F) + \frac{\phi + 2H}{\phi + 3H} \varepsilon_S.
\] (C4c)

with \( H \) as defined before.
Three countries, EMU

Again, the derivation is analogous to the solution for the two-country case with decentralised policy making and without commitment. The expected inflation in Europe and expected German tax rate (under the assumption of rational expectations) under EMU are:

\[
\pi_E^* = \frac{\phi \beta}{\phi + k(\phi \beta + 2\gamma)}(k\pi_E^* + y_E^*), \quad (C5a)
\]

\[
t_G^* = \frac{1}{\phi + 2k\gamma}(\phi \pi_G^* - 2\gamma y_G^*) + \frac{\phi^2 \mu \beta}{(\phi + 2k\gamma)(\phi + k\phi \beta + 2k\gamma)}(k\pi_E^* + y_E^*), \quad (C5b)
\]

where the French tax rate follows by symmetry. The coefficients for the US are the same as in the two-country case.

Under EMU, the response of inflation and tax rates (in deviation from their expected value) to shocks is:

\[
\pi_E^d = -\frac{\beta}{2(\phi + \gamma + 2H)}[\phi(\varepsilon_G + \varepsilon_F) + H(\varepsilon_G + \varepsilon_F + 2\varepsilon_S)], \quad (C6a)
\]

\[
t_G^d = \frac{\phi \mu \beta + 2\gamma}{2(\phi + \gamma + 2H)}[\phi(\varepsilon_G + \varepsilon_F) + H(\varepsilon_G + \varepsilon_F + 2\varepsilon_S)] + \frac{\gamma}{\phi + 6\gamma}(\varepsilon_G - \varepsilon_F). \quad (C6b)
\]

By symmetry, the French tax response is equal to the German tax response apart from switching all subscripts for Germany and France. The response of inflation and tax rates in the United States is:

\[
\pi_S^d = -\frac{1}{2}[\frac{\beta}{\phi + \gamma + 2H}][2\phi \varepsilon_S + (\gamma + H)(\varepsilon_G + \varepsilon_F + 2\varepsilon_S)], \quad (C7a)
\]

\[
t_S^d = \frac{1}{2}[\frac{\phi \mu \beta + \gamma}{\phi(\phi + \gamma + 2H)}][2\phi \varepsilon_S + (\gamma + H)(\varepsilon_G + \varepsilon_F + 2\varepsilon_S)], \quad (C7b)
\]

with \( H \) defined as before. Combining these results with the supply functions and budget constraints yields the solution for Germany in terms of the determinants of welfare and the other variables in the EMU analogon of equation (3.22).\textsuperscript{60} The solution is shown in Table C2.

\textsuperscript{60}The EMU analogon of equation (3.22) is simply found by substituting \( \pi_E \) for \( \pi_G \) and \( \pi_F \).
### Table C2  Solution to three-country game under EMU

<table>
<thead>
<tr>
<th>variable</th>
<th>deterministic component</th>
<th>stochastic component</th>
</tr>
</thead>
<tbody>
<tr>
<td>$y_E^* - y_G$</td>
<td>$\frac{\phi}{\phi + k(\phi\mu^3 + 2\gamma)} [g_E^* + y_E^* + (k - 1)g_E^*]$</td>
<td>$-\epsilon_{G, EMU}^{comp}$</td>
</tr>
<tr>
<td>$g_E^* - g_C$</td>
<td>$\frac{2k\gamma}{\phi + k(\phi\mu^3 + 2\gamma)} [g_E^* + y_E^* - \left(\frac{k - 1}{k}\right)g_E^*]$</td>
<td>$-2\gamma \epsilon_{G, EMU}^{comp}$</td>
</tr>
<tr>
<td>$\mu \pi_E$</td>
<td>$\frac{k\phi\mu^3 + 2k\gamma}{\phi + k(\phi\mu^3 + 2\gamma)} [g_E^* + y_E^* - \left(\frac{k - 1}{k}\right)g_E^*]$</td>
<td>$-\mu(\beta + \frac{2\gamma}{\phi}) \epsilon_{\pi_E, EMU}^{comp}$</td>
</tr>
<tr>
<td>$-k(1-t^e_G)$</td>
<td>0</td>
<td>$-\beta \epsilon_{\pi_E, EMU}^{comp}$</td>
</tr>
<tr>
<td>$t_F - t^e_F$</td>
<td>(\mu + \frac{2\gamma}{\phi}) \epsilon_{t_F, EMU}^{comp}$</td>
<td></td>
</tr>
<tr>
<td>$-\pi_E - \pi_S^*$</td>
<td>0</td>
<td>$\beta \epsilon_{\pi_S, EMU}^{comp}$</td>
</tr>
<tr>
<td>$t_S - t^e_S$</td>
<td>(\mu + \frac{2\gamma}{\phi}) \epsilon_{t_S, EMU}^{comp}$</td>
<td></td>
</tr>
</tbody>
</table>

where

\[
\begin{align*}
\epsilon_{G, EMU}^{comp} &= \frac{\phi + H}{\phi + \gamma + 2H} \epsilon_E + \frac{\phi}{\phi + 6\gamma} \epsilon_{G-E} + \frac{H}{\phi + \gamma + 2H} \epsilon_S; \\
\epsilon_{F, EMU}^{comp} &= \frac{\phi + H}{\phi + \gamma + 2H} \epsilon_E + \frac{\phi}{\phi + 6\gamma} \epsilon_{F-E} + \frac{H}{\phi + \gamma + 2H} \epsilon_S; \\
\epsilon_{S, EMU}^{comp} &= \frac{\gamma + H}{\phi + \gamma + 2H} \epsilon_E + \frac{\phi + \gamma + H}{\phi + \gamma + 2H} \epsilon_S.
\end{align*}
\]

(C8a) (C8b) (C8c)

with $\epsilon_E = \frac{1}{2}(\epsilon_G + \epsilon_F)$, $\epsilon_{G-E} = \epsilon_G - \epsilon_E$, $\epsilon_{F-E} = \epsilon_F - \epsilon_E$, $\epsilon_{G, EMU}^{comp} = \frac{1}{2}(\epsilon_{G, EMU}^{comp} + \epsilon_{F, EMU}^{comp})$ and $H$ as defined before. Again, the deterministic components of the variables in Table C2 add up to $g_E^* + y_E^*$, as required by the EMU analogon of equation (3.22) in the main text. The stochastic components of the German variables in Table C2 are functions of the composite shock $\epsilon_{G, EMU}^{comp}$. The stochastic components of the variables in Table C2 add up to $-\epsilon_G$, as required.