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Corresponding authors: P.A.D. Cavelaars
e-mail: p.a.d.cavelaars@dnb.nl

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De Nederlandsche Bank NV
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The Welfare Cost of Structural Distortions and Stochastic Shocks

Paul Cavelaars
De Nederlandsche Bank and Ocfeb Center for Economic and Financial Policy Research, Erasmus University

Abstract
This paper develops a monetary-fiscal game which stresses the importance of international spillovers and introduces a double (monetary and fiscal) credibility problem. Models that neglect the inability of fiscal policymakers to commit will tend to underestimate the welfare cost of structural distortions. Due to international spillovers, stochastic shocks may be relatively costly in welfare terms, despite the contribution of policy surprises to finance such shocks.

Key words: commitment, spillovers, welfare analysis.
JEL codes: E610, F330.

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1 Introduction

Structural distortions and stochastic shocks both generate welfare losses, as they make it more difficult for policymakers to attain their pre-specified goals. This paper sets out to evaluate the welfare costs of structural distortions compared to the welfare costs of stochastic shocks.

The model in this paper specifies a policy game involving central banks and fiscal authorities. The policy game takes place in a world of two countries. Monetary policy is determined by independent central banks. The supply function, which is based on Martin (1997), stresses the importance of cross-border spillovers. I extend Martin’s basic model in a number of ways. Fiscal authorities are explicitly modeled, I allow for structural distortions and commitment problems and I provide a (simple) behavioural motivation for the supply curves. The first extension makes it possible to consider the interactions between monetary and fiscal policymakers. The other extensions allow me to conduct a meaningful welfare evaluation.

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

The remainder of this paper is organised as follows. In the next section, I develop a framework for welfare evaluation. I do this by specifying a two-country model for a policy game involving central banks and fiscal authorities. The model stresses the importance of international spillovers. When negative supply shocks occur, countries compete for economic activity through tax cuts and surprise inflation. The analysis takes into account that both monetary and fiscal authorities face a commitment problem. Section 3 solves the model and discusses the solution. Section 4 concludes.
2 A two-country model

In this section, a two-country monetary-fiscal policy game is developed.

2.1 Output

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

\[
\begin{align*}
y_1 &= -kt_1^e - (w_1 - p_1 + t_1 - t_1^e) + (w_2 - p_2 + t_2 - t_2^e) + \varepsilon_1, \quad (1a) \\
y_2 &= -kt_2^e + (w_1 - p_1 + t_1 - t_1^e) - (w_2 - p_2 + t_2 - t_2^e) + \varepsilon_2, \quad (1b)
\end{align*}
\]

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

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

The above functions for supply per capita have the following characteristics. First, output is negatively correlated with the real wage rate (i.e. a money surprise) and a tax surprise in the home country. Secondly, output is positively correlated with the foreign real wage and a foreign tax surprise. This is how international spillovers enter the model. Finally, output is negatively related to the domestic expected tax rate. Output is more responsive

---

2As follows from Appendix A, output is more responsive to the expected tax rate than to a tax surprise. In order to reflect this, I assume \( k > 1. \)
to the *expected* tax rate than to a tax *surprise*. The reason is that workers are hired at an early stage, so that firms are locked in to a certain total supply level (but not to the production location) before taxes are set. Firms lose a degree of freedom between the moment they form expectations on the tax rate and the moment that tax surprises realise. Intuitively, firms are more responsive to the tax environment before they have made substantial investments than after they have done so. In other monetary-fiscal models, taxes enter the supply function, but foreign variables and the domestic expected tax rate usually do not.

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

\[
\begin{align*}
y_1 &= -k\ell_1^e + (\pi_1 - \pi_1^e - t_1 + \ell_1^e) - (\pi_2 - \pi_2^e - t_2 + \ell_2^e) + \varepsilon_1, \quad (2a) \\
y_2 &= -k\ell_2^e - (\pi_1 - \pi_1^e - t_1 + \ell_1^e) + (\pi_2 - \pi_2^e - t_2 + \ell_2^e) + \varepsilon_2, \quad (2b)
\end{align*}
\]

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

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

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

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

Fiscal authorities set taxes and spending in order to minimise:

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

(3)

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

I will assume that \( \phi \) and \( \gamma \) are equal across countries. However, the targets \( y_i^* \) and \( g_i^* \) may differ across countries.\(^3\)

The government budget constraint is:\(^4\)

\[ g_i = t_i + \mu \pi_i, \quad i = 1, 2, \]  

(4)

where \( \mu (>0) \) represents the (constant) ratio of real money holdings as a share of the first-best level of output in equilibrium, i.e. in the absence of distortions and economic shocks.\(^5\)

When adverse shocks occur, each government has an incentive to inflate away the domestic real wage and to cut taxes in order to import jobs and production from the foreign country (Martin, 1997). Cutting taxes and creating inflation are beggar-thy-neighbour policies in this model, in the sense that they harm foreign output [see equations (2a)-(2b)].

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

\(^3\)One could argue that a high level of \( g^* \) is typical for a continental-European government, which finds it important to provide an adequate level of public goods and services, whereas a low level of \( g^* \) would be typical for an Anglo-Saxon government, whose main goal would be to increase the economic growth potential by a policy of ‘small government’ and a low level of taxation, in order not to create too many distortions. Later on, I will allow for this possibility by distinguishing between \( g^*_E \) (for Europe) and \( g^*_S \) (for the United States). However, the focus here is not on the level of the government spending target, but on the relative weights attached to the spending and output targets, respectively.

\(^4\)In this paper, the terms government and fiscal authorities are used interchangeably.

\(^5\)The budget constraint is derived using the Fisher equation. It is assumed that real money demand does not depend on expected inflation. See Beetsma and Bovenberg (1999a) for a derivation of a more general version of this constraint.
\[ L_i^{CB} = \frac{1}{2}\sigma_i^2 + \beta(y_i - y_i^*)^2, \quad i = 1, 2. \] (5)

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 $\beta$ will generally differ from $\gamma$. I 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 are formed.

### 2.3 Framework for welfare evaluation

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

\[ y_i^* + g_i^* - \varepsilon_1 = (y_i^* - y_1) + (g_i^* - g_1) + \mu \pi_1 + \]
\[ + (\pi_1 - \pi_1^e) - (k - 1)t_1^e - (\pi_2 - \pi_2^e) + (t_2 - t_2^e). \] (6)

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

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

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

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

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

3 Solution and discussion

3.1 Solution of the model

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

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

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

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

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

$$\pi_E = -\beta(y_E - y^*_E).$$

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

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

3.2 Distortions and commitment problems

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

The impact of the distortions on the tax rate is more subtle. A high target for government spending $g^*_E$ leads to a high expected tax rate. Intuitively, a high target share of government spending will have to be matched by high government revenues. By contrast, a high level of non-tax distortions $y^*_E$ leads to a low expected tax rate. Intuitively, non-tax distortions will erode the tax base (output), increasing the relative attractiveness of seigniorage over output tax as an instrument to generate government revenues. Moreover, an increase in taxes is relatively costly in terms of welfare if the level of non-tax distortions is high, because it widens further the deviation of output from its target.
Table 1  Solution to the two-country game

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

where

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

I will, realistically, assume that policymakers are unable to commit. Nominal wages are influenced by the expected inflation rate, but cannot adjust to an inflation surprise. This causes the familiar time-inconsistency of monetary policy. The absence of monetary policy commitment gives rise to an upward inflation bias. Fiscal policy is subject to a time-inconsistency problem as well. Stimulating output requires reducing the tax rate, whereas an increase in government spending calls for raising the tax rate. Output is less responsive to a tax surprise than to the expected tax rate. This means that the optimal tradeoff shifts in favour of a higher tax rate after the private sector has formed expectations about tax rates. Firms are aware of the fact that the fiscal authorities have an incentive to announce a

6Recall that the total amount of labour is fixed when workers are hired. Therefore, firms lose a degree of freedom between the moment when they form expectations about the tax rate and the moment when the tax surprise materialises.
lower tax rate than they will choose ex-post. Therefore, the absence of fiscal commitment gives rise to an upward tax bias. Intuitively, the monetary time-inconsistency problem is caused by the short-run rigidity of nominal wages, whereas the fiscal time-inconsistency problem is caused by short-run constraints on output (although the model does not formally distinguish between the short run and the long run).

Time-inconsistencies arise both via the wage rate and via output in my model. By contrast, in Alesina and Tabellini (1987) and Bryson, Jensen, Van Hoose (1993), time-inconsistencies arise only via the wage rate. In Alesina and Tabellini (1987), tax rates enter the supply curve, but fiscal policy is not subject to time-inconsistencies.\(^7\) In Bryson, Jensen, Van Hoose (1993), fiscal policy is subject to time-inconsistencies. The contracted nominal wage rate depends negatively on the expected tax rate. In their model, as in mine, expected and unexpected tax cuts stimulate output. In their model, output is more sensitive to a surprise tax cut than to an expected tax cut, which gives rise to a downward tax bias. In my model, by contrast, output is more sensitive to an announced tax cut than to a surprise tax cut. Fiscal authorities compete for multinational firms by offering an attractive tax environment. However, sovereign countries cannot make a credible commitment that the tax treatment will not be changed after multinational firms have made substantial investments in the country.

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

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

\(^7\) In Alesina and Tabellini (1987), the wage rate as set by the labour unions depends on expected inflation, but not on the expected output tax rate. There is also no impact of taxes on wages via the inflation rate, as central banks directly control the inflation rate. Therefore, the impact of taxes on output is the same before and after nominal wages are determined. Thus, fiscal policy is not subject to time-inconsistencies.
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 ($\mu$). First, a fiscal authority which is inclined to close the output gap rather than the spending gap ($\frac{\phi}{\gamma} \text{ high}$) 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. Second, 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. Third, a large real money stock ($\mu \text{ high}$) means that there is a large inflation tax base, making it more attractive to create inflation in order to generate government revenues. On the other hand, a lower inflation rate would be needed to generate the same level of government revenues. It turns out that the latter dominates the former: the equilibrium inflation rate will be lower. Nevertheless, seigniorage makes a more significant contribution to government revenue. This makes it easier for the fiscal authority to achieve its policy targets. The fiscal authority is able to lower its tax rate and simultaneously increase government spending. The lower tax rate induces a higher level of output, which implies that there is less of a need for the central bank to raise inflation in order to protect employment.

### 3.3 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 $g^*_S$ and $y^*_S$. This feature of the model fits reality, in the sense that policymakers tend to be more concerned about possible international spillovers from an unexpected adverse foreign shock, than about known structural distortions in a foreign country.

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

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

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

\[-(1 + \beta + \frac{\gamma}{\phi})(\varepsilon_E + \varepsilon_S).\]  \hspace{1cm} (10)

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

3.4 Welfare

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

\[E(L_E) = \frac{\phi\beta^2 + \phi \gamma + \frac{\gamma^2}{\phi}}{2\phi} \frac{\phi^2}{(\phi + k \mu \beta + k \gamma)^2} \frac{(k g^*_E + y^*_E)^2}{(\phi + H)^2} + \frac{(\phi + 2H)^2 + H^2}{(\phi + 2H)^2} \sigma^2].\]  \hspace{1cm} (11)
Society’s welfare is thus composed of a term arising from deterministic distortions and a term associated with stochastic (supply) shocks. Examples of these structural distortions are union control over the labour market and monopoly control over commodity markets. Examples of unanticipated shocks are oil price shocks and a credit crunch. Let us look at the implications of the fiscal commitment problem and international spillovers for welfare.

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

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

In the current model, it is ambiguous whether financing the deterministic component is more or less costly in terms of welfare than financing the stochastic component. The contribution of inflation surprises to financing the stochastic component may be more than offset by the welfare-reducing impact of foreign monetary and fiscal policy responses to shocks. Beetsma and Bovenberg (1999b) show that in the context of their model, it is less costly to finance stochastic shocks than deterministic distortions, as inflation surprises can contribute to financing the stochastic component and not to financing the deterministic component. Thus, the assertion by Beetsma and Bovenberg that it is less costly to finance stochastic shocks does not necessarily hold here.

---

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

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

The model in this paper stresses the importance of cross-border spillovers and introduces a double (monetary and fiscal) credibility problem. It extends a model by Martin (1997) to take into account the interaction between monetary and fiscal policy.

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

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

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

A Derivation of supply functions

A.1 Output in N identical countries

The world consists of $N$ identical countries of size 1. Capital is assumed to be fixed. Therefore, output in each economy is a function of labour input only: $Y_i = L_i^\eta e^{\xi_i}$, $i = 1, ..., N$, where $Y_i$ is real output, $L_i$ is labour input and $\xi_i$ is a normally distributed, idiosyncratic shock with finite variance and expected value zero that hits country $i$ (i.e. $E \xi_i = 0$, $Var(\xi_i) = (\sigma^*)^2$, $i = 1, ..., N$). 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.\footnote{This particular set-up helps to highlight the cross-border impact of government policies. Intuitively, countries compete for being a favourable production site.} The representative firm maximises profits under the constraint that the size of the total workforce is pre-determined.

$$\begin{align*}
Max \quad & \prod_i (1 - t_i)P_i Y_i - W_i L_i + \\
& + \sum_{j \neq i} X_{ij}[(1 - t_j)P_j Y_j - W_j L_j], \\
\text{s.t.} \quad & \sum_j L_j = L^*,
\end{align*}$$

(A1)

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

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

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

\[
\frac{(1-t_i)\eta L_i^{\eta-1} e_i}{(1-t_j)\eta L_j^{\eta-1} e_j} - 1 = \frac{W_i/P_i}{W_j/P_j} - 1, \quad \forall j \neq i. \tag{A3}
\]

Eliminate corresponding terms, take logs and add all \(N-1\) equations. Use equation (A9) below and the fact that the total number of employees is predetermined. Approximate \(\log(1-t_i)\) by \(-t_i\). The production function in terms of logs is:

\[
y_i = \eta l_i + \xi_i. \tag{A4}
\]

where \(\epsilon_i\) is a random shock with expectation zero and finite variance.

**Step 4:** Monetary and fiscal policies are set. See the main text (Section 2).

**Step 3:** Shocks occur. No optimisation takes place in this step.

**Step 2:** The representative firm hires the number of workers which will maximise expected total firm profits (expressed in the currency of country \(i\)):

\[
\max_{(L_1, \ldots, L_N)} \Pi = E\{ (1-t_i)P_i Y_i - W_i L_i^* + \sum_{j \neq i} X_{ij}[(1-t_j)P_j Y_j - W_j L_j^*] \}. \tag{A5}
\]

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. 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, (A5) can be rewritten as

\[
\max_{(L_1^*, \ldots, L_N^*)} \Pi = (L_i^*)^\eta E[(1-t_i)P_i e^{\xi_i}] - W_i L_i^*, \quad i = 1, \ldots, N. \tag{A6}
\]
The first-order condition for the maximisation of profits in country $i$ is:

$$\eta(L^*_{ri})^{y-1}E\{(1-t_i)P_t e^{x_i}\} = W_i.$$  \hspace{1cm} (A7)

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

$$\log \eta + (\eta - 1)t^*_i - t^*_i = w_i - p^*_i, \quad i = 1, ..., N.$$  \hspace{1cm} (A8)

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

$$l^*_i = \left(\frac{1}{1 - \eta}\right)(-t^*_i + \log \eta),$$  \hspace{1cm} (A9)

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

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

## B Derivation of solutions: two countries

In this appendix, the two-country model given by equations (2)-(5) 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.

**Full commitment, single policy maker in each country**

It is assumed that policymakers 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) 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 (2) and the budget constraints (4) 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:

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

Combining (B1a)-(B1b) with equations (2) and (4) yields the solution in terms of the determinants of welfare $(y_E^* - y_E, g_E^* - g_E, \mu\pi_E)$ and the other variables in equation (6) 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{11}

\textsuperscript{11}Note that $g_E^* - g_E$ and $y_E^* - y_E$ 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.
Full commitment, decentralised policy making

The responsibility for monetary policy is delegated to an independent central bank.\textsuperscript{12}

There are now four policy makers, who play Nash against each other. The loss functions are given by equations (3) and (5) 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 budget. The first-order conditions for the euro area authorities are:

\begin{align}
\phi(g_E^* - g_E^*) &= k\gamma(y_E^* - y_E^*), \quad \text{(B2a)} \\
\pi_E^* &= 0. \quad \text{(B2b)}
\end{align}

Combining (B2a)-(B2b) with equations (2) and (4) in the main text yields the deterministic components of the reduced-form solution, as shown in Table B1. The optimal tradeoff between spending stabilisation and output stabilisation 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 with $\mu = 0$.

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.\textsuperscript{13}

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 $E(\pi_i) = \pi_i^\text{e}$ before taking first-order conditions,\textsuperscript{12}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.\textsuperscript{13}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.
whereas $E(t_i) = t_i^*$ is imposed afterwards. The resulting conditions for the euro area authorities are:

$$\phi(g_E^* - g_E^+) = \gamma(y_E^* - y_E^+),$$  \hspace{1cm} (B3a)

$$\pi_E^* = 0.$$  \hspace{1cm} (B3b)

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, they 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 will promise a low tax rate and hike taxes after firms have invested in human capital. Firms are aware of this possibility and adjust 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.

**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 $E(\pi_i) = \pi_i^*$ after taking first-order conditions. Therefore, the deterministic and stochastic parts of the model can be solved simultaneously. The resulting conditions are:

$$\pi_E^* = -\beta(y_E^* - y_E^+),$$  \hspace{1cm} (B4a)

$$\phi(g_E^* - g_E^+) = \gamma(y_E^* - y_E^+).$$  \hspace{1cm} (B4b)

Combining (B4a)-(B4b) with equations (2) and (4) 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 are aware of this, so that the possibility to cheat has an optimal upward effect on their inflation expectations.
### 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 + \gamma)} [g^<em>_E + y^</em>_E + (k-1)g_E^*] )</td>
<td>( \frac{\phi}{\phi + k^2(\phi \mu + \gamma)} [g^<em>_E + y^</em>_E + (k-1)g_E^*] )</td>
</tr>
<tr>
<td>( g^*_E - g_E )</td>
<td>( \frac{k^2 \gamma}{\phi + k^2(\phi \mu + \gamma)} [g^<em>_E + y^</em>_E - \left( \frac{k-1}{k} \right) g_E^*] )</td>
<td>( \frac{k^2 \gamma}{\phi + k^2(\phi \mu + \gamma)} [g^<em>_E + y^</em>_E - \left( \frac{k-1}{k} \right) g_E^*] )</td>
</tr>
<tr>
<td>( \mu \pi E )</td>
<td>( \frac{k^2 \phi^2 \mu^2}{\phi + k^2(\phi \mu + \gamma)} [g^<em>_E + y^</em>_E - \left( \frac{k-1}{k} \right) g_E^*] )</td>
<td>0</td>
</tr>
<tr>
<td>( -(k-1)t_E )</td>
<td>( \frac{k^2(\phi \mu + \gamma)}{\phi + k^2(\phi \mu + \gamma)} \left( \frac{k-1}{k} \right) y_E^* + \frac{k^2 \gamma}{\phi + k^2(\phi \mu + \gamma)} (k-1)g_E^* )</td>
<td>( \frac{k^2 \gamma}{\phi + k^2(\phi \mu + \gamma)} (k-1)g_E^* )</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>variable</th>
<th>monetary commitment, monetary discretion, 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 + \gamma)} [g^<em>_E + y^</em>_E + (k-1)g_E^*] )</td>
<td>( \frac{\phi}{\phi + k^2(\phi \mu + \gamma)} [g^<em>_E + y^</em>_E + (k-1)g_E^*] )</td>
</tr>
<tr>
<td>( y^*_E - y_E )</td>
<td>( \frac{k^2 \gamma}{\phi + k^2(\phi \mu + \gamma)} [g^<em>_E + y^</em>_E - \left( \frac{k-1}{k} \right) g_E^*] )</td>
<td>( \frac{k^2 \gamma}{\phi + k^2(\phi \mu + \gamma)} [g^<em>_E + y^</em>_E - \left( \frac{k-1}{k} \right) g_E^*] )</td>
</tr>
<tr>
<td>( \mu \pi E )</td>
<td>0</td>
<td>( \frac{k \phi \mu}{\phi + k^2(\phi \mu + \gamma)} [g^<em>_E + y^</em>_E - \left( \frac{k-1}{k} \right) g_E^*] )</td>
</tr>
<tr>
<td>( -(k-1)t_E )</td>
<td>( \frac{k^2(\phi \mu + \gamma)}{\phi + k^2(\phi \mu + \gamma)} \left( \frac{k-1}{k} \right) y_E^* + \frac{k^2 \gamma}{\phi + k^2(\phi \mu + \gamma)} (k-1)g_E^* )</td>
<td>( \frac{k^2 \gamma}{\phi + k^2(\phi \mu + \gamma)} (k-1)g_E^* )</td>
</tr>
</tbody>
</table>

### 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)

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)

Combining these equations with their US counterparts and with equations (2) and (4) yields the solution in terms of the determinants of welfare and the other variables in equation (6) 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)
Take expectations on both sides of these equations and subtract the resulting equations from (B7a)-(B7b). This results in

\[
\phi(g_E - g_E^E) = \gamma(y_E - y_E^E), \quad \text{(B8a)}
\]
\[
\pi_E - \pi_E^E = -\beta(y_E - y_E^E). \quad \text{(B8b)}
\]

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.\(^{14}\)

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^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^E)</td>
<td>(-\frac{\gamma}{\phi}(A\varepsilon_E + B\varepsilon_S))</td>
<td>(-\frac{\gamma}{\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^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^E)</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^E)</td>
<td>(\frac{\phi\mu\gamma(1 + \mu) + \gamma}{\phi}(B\varepsilon_E + A\varepsilon_S))</td>
<td>(\frac{\phi\mu\beta + \gamma}{\phi}(L\varepsilon_E + K\varepsilon_S))</td>
</tr>
</tbody>
</table>

where

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

\(^{14}\)A conservative central bank has a relatively strong preference for low inflation (i.e. \(\beta < \gamma\)). See, for instance, DeBelle (1996).
and

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


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<td>P. Bacchetta and E. van Wincoop</td>
<td>A Theory of the Currency Denomination of International Trade</td>
</tr>
<tr>
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