Supply policies coordination in a monetary union

Carmen Díaz-Roldán[1]
Universidad Pública de Navarra

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Abstract

This paper examines how the member countries of a monetary union react to country-specific shocks and to shocks from the rest of the world, using supply-side policies.We develop a three-country model in which countries show different preferences regarding objectives, and face asymmetric disturbances. Two of the countries form a monetary union where an independent central bank controls monetary policy, and supply policies are determined by the authorities at the national level. In this framework, we analyse in strategic terms how the authorities can deal with monetary, real and supply shocks, and discuss the welfare aspects of the optimal solution and the extent to which a coordinated supply-side policy may be useful to deal with those shocks.

Key words: Monetary union, supply-side policies, policy coordination.
JEL Classification: E61, E62, F42.

Contents

1 Introduction

The costs of losing the exchange rate and monetary policy as instruments of macroeconomic stabilization, acquire a special importance when deciding the convenience of forming a monetary union. Most of the theoretical and empirical studies conclude that these costs will depend on the asymmetry of the shocks. So, for instance, Bayoumi and Eichengreen (1993) find that the costs imposed by asymmetric shocks in the European monetary union will be larger, since these shocks require country-specific adjustment policies.

Other question broadly discussed is that, in the absence of fully flexible prices and wages, as well as labour mobility as adjustment mechanisms, governments have to deal with shocks using mainly fiscal policy. But the disciplining effects of a monetary union may require some limitations on the use of fiscal policy. We can mention, as an example, the fiscal discipline imposed by the Pact for Stability and Growth in the European Monetary Union (EMU). Since fiscal policy in monetary unions may be inefficient, the possibility for fiscal policy coordination has been discussed; the conditions for which fiscal policy coordination may be useful are derived in Díaz (1998).

On the other hand, given the limitations of fiscal policy, it would be desirable to have other alternative policies available; among them, the possibility of using supply-side policies has been discussed (Jimeno, 1992). From a different point of view, this idea had been mentioned in the literature on optimum currency areas: countries with similar inflation rates would be good candidates to join a common currency area, being this feature related to the institutional mechanisms of the labour market (Calmfors and Driffill, 1988). This argument could support the need for some harmonization of the institutional mechanisms governing labour market reforms of the countries forming a monetary union, as an useful tool for reducing the cost of belonging to a common currency area.

The available literature has hardly studied supply-side policies. De Miguel and Sosvilla (1996) develop a two-country model in order to analyse the effects of macroeconomic policies in a monetary union, with different wage rigidities. Supply policies are represented by changes in the employers social security contributions, having a direct impact on real wages. On the other hand, Sibert and Sutherland (1997) develop an intertemporal n-country model to study the role of labour market reforms on the costs and benefits of monetary integration. They conclude that in a monetary union the labour market reform is lower than in other monetary policy regime. In relation with this paper, this result could justify the interest of analysing the way of implementing the labour reform: individually, by establishing some agreements about supply policies, or by the way of supply policy coordination.

In this paper we examine how the member countries of a monetary union can react to asymmetric shocks by using supply-side policies. To this end, we develop a three-country model where countries show different preferences regarding objectives and face asymmetric (monetary, real and supply) shocks. Two of the countries form a monetary union where an independent central bank controls monetary policy, and supply policies are determined by the authorities at the national level. Next, we analyse in strategic terms how the authorities can deal with shocks using as instrument an institutional variable affecting the wage negotiation process. The authorities can act individually or cooperatively and, in the rest of our paper, we identify authorities cooperation with policy coordination.

As an original contribution of this paper, first or all, we can mention that the model has been explicitly designed for a monetary union. This type of models are not frequent in the literature, and we have used an extension of the model developed in Díaz (1998). An important result derived from our analysis is that the desirability of supply-side policies coordination is not only related to the characteristics of the shocks, but it is also related to how their effects are transmitted among countries. In addition, the role played by the channel of transmission of the shocks will be determinant for the results. Secondly, we analyse the role of supply policies, something that have been hardly discussed in the literature. We use as instrument an institutional variable that can affect both the degree of price and wage flexibility, and the wage negotiation process. This kind of policy has been previously proposed in order to deal with shocks and to avoid the adverse effects of unemployment (see, e.g., Viñals and Jimeno, 1996). Since policies of structural reforms and supply-side policies are presumed to be useful to deal with labour market inefficiencies, our institutional variable could also be interpreted as a way of harmonization of the labour market institutions. In particular, that variable could be thought more as an instrument designed to modify the institutional mechanisms of labour market, rather than a stabilization tool.

The main results of the paper are, first, that supply-side policy coordination between the member countries of the union would be counterproductive when aggregate demand is the channel of transmission of the shocks, independently of the nature (demand-side or supply-side) and the origin of the shocks (a country of the union or the rest of the world). Second, when the interest rate and the exchange rate are the channel of transmission of the shocks, cooperation would result counterproductive when dealing with monetary and supply shocks independently of their origin, and with real shocks from the rest of the world; however, cooperation would prove to be useful against real shocks from the monetary union.

The paper is structured as follows. In section 2 a theoretical model for a monetary union is developed, which will allow us to study the effects of shocks on the union's member countries. Next, the possibilities for supply policies coordination are analysed in strategic terms in section 3; whereas the welfare aspects of the optimal solution are discussed in section 4. Finally, section 5 concludes.

2 The model

We will consider a model of two symmetric economies: the monetary union and the rest of the world, with flexible exchange rates and perfect capital mobility between them. All the variables are defined as rates of change and those from the rest of the world are denoted with an asterisk.

The monetary union is described by the following set of equations, where all parameters, denoted by Greek letters, are nonnegative:

$$y = -\alpha r_{\mathrm{W}} + \gamma g + \beta(e_{\mathrm{W}} + p^{*} - p) + \delta y^{*} + f \quad (1)$$

$$m - p = \theta y - \psi r_{\mathrm{W}} \quad (2)$$

$$p_c = (1-\mu)p + \mu(p^{*} + e_{\mathrm{W}}) \quad (3)$$

$$w - \varepsilon p_c = \phi prod - \eta u + z - v - t \quad (4)$$

$$p - w = -\phi prod - \varphi u \quad (5)$$

$$y^{s} = n + prod \quad (6)$$

Equation (1) represents the goods market equilibrium condition. Output depends on the world interest rate r_{W}, the budget deficit g, the real exchange rate between the union and the rest of the world $(e_{\mathrm{W}} + p^* - p)$, the rest of the world's output y^*, and a positive real shock f. Notice that the assumption of perfect capital mobility implies that $r = r^* = r_{\mathrm{W}}$. We also assume that the Marsall-Lerner condition holds, so that a real exchange rate depreciation leads to a positive effect on the balance of trade and the output of the monetary union, which implies β to be positive.

Equation (2) shows the money market equilibrium condition, where m denotes the union's money supply, and the demand for money depends on the union's output and the world interest rate.

Equations (3) to (6) represent the aggregate supply of the economy, built along the lines of Layard, Nickell and Jackman's (1991) model, (see also Nickell (1990) for a survey). Equation (3) is the definition of the consumer price index p_c, as a weighted average of the union goods' and the imported goods' prices in terms of the common currency.

Equation (4) shows that nominal wages are determined by the degree of indexation with respect to the consumer price index, depending on ε; labour productivity, $prod$; the unemployment rate, u; wage pressure factors, z; the way in which agents form their expectations, captured by the variable v; and the use, as a policy instrument, of an institutional variable t, which affects the wage setting process.

The parameter ε denotes the degree of wage rigidity, with $0 \leqq \varepsilon \leqq 1$. The value $\varepsilon = 1$ implies real wage rigidity, so that nominal wages are fully indexed to changes in the consumer price index; whereas if $\varepsilon = 0$ we have nominal wage rigidity. In our model, we will assume the intermediate case so that $0 < \varepsilon < 1$.

On the other hand, the effects of expectations on the consumer price index is captured by the variable v. In a "*New Classical Macroeconomics*" framework, assuming rational expectations, the discrepancies between the actual change in the consumer price index and its expected change is due to the agents' mistakes, purely random, i.e.: $p_c - p_c^e = error$, so that $v = \varepsilon\ error$, and if $\widehat{e}$ is equal to zero (the agents do not make mistakes) for $\varepsilon \neq 0$, the unemployment rate obtained from equations (4) and (5) will be the *natural rate of unemployment.* Alternatively, in a "*New Keynesian Macroeconomics*" framework, if the agents form their expectations assuming that the expected change of the consumer price index is equal to its change in the previous period, $p_c^e = p_{c,-1}$, then $p_c - p_c^e = p_c - p_{c,-1} = \Delta\, p_c$, and $v = \varepsilon\Delta\, p_c$. In that case, for $\varepsilon \neq 0$, the unemployment rate obtained from equations (4) and (5) will be the *NAIRU.* Therefore, this general formulation allows us to include both models (*New Classical* and *New Keynesian*) as particular cases.

In equation (5), prices are set by adding a margin to wages, which depends on productivity, *prod*, and the unemployment rate, u. We also assume that the parameter ϕ is the same that in the wage-setting equation (4). This assumption, which simplifies the analysis without altering the basic results, is commonly used in the literature, and is justified since in the long term productivity changes do not affect the unemployment rate (see e.g. Layard, Nickell and Jackman (1991)).

Finally, equation (6) defines changes in output as the sum of changes in employment, n , and productivity, *prod*.

The second economy analysed is the rest of the world. As mentioned earlier, we develop a model for two symmetric economies; therefore, equations describing the rest of the world are equivalent to the monetary union's equations. We also assume asymmetric shocks in origin leading to different effects on the union and the rest of the world, so we have the following set of equations:

$$y^* = -\alpha r_{\text{W}} - \beta(e_{\text{W}} + p^* - p) + \delta y + f^* \tag{7}$$

$$m^* - p^* = \theta y^* - \psi r_{\text{W}} \tag{8}$$

$$p_c^* = (1-\mu)p^* + \mu(p - e_{\text{W}}) \tag{9}$$

$$w^* - \varepsilon p_c^* = \phi prod^* - \eta u^* + z^* - v^* \tag{10}$$

$$p^* - w^* = -\phi prod^* - \varphi u^* \tag{11}$$

$$y^{*s} = n^* + prod^* \tag{12}$$

Notice that in the goods market equilibrium condition, we neglect the fiscal variable g^*, which is implicitly included in the real shock f^*. We also neglect the institutional variable t^*, implicity included in the supply shock s^*(see below).

From equations (1) to (6) for the monetary union and (7) to (12) for the rest of the world, we can obtain the aggregate demand functions for each economy:

$$y^d = \frac{\alpha}{\psi + \alpha\theta}(m-p) + \frac{\beta\psi}{\psi + \alpha\theta}(e_{\text{W}} + p^* - p) + \frac{\delta\psi}{\psi + \alpha\theta}y^{*d} + \frac{\gamma\psi}{\psi + \alpha\theta}g + \frac{\psi}{\psi + \alpha\theta}f \tag{13}$$

$$y^{*d} = \frac{\alpha}{\psi + \alpha\theta}(m^* - p^*) - \frac{\beta\psi}{\psi + \alpha\theta}(e_{\text{W}} + p^* - p) + \frac{\delta\psi}{\psi + \alpha\theta}y^d + \frac{\psi}{\psi + \alpha\theta}f^* \tag{14}$$

Combining the definition of the consumer price index (3) with the aggregate supply equations, (4) to (6), and replacing $u = l - n$ (where l denotes active population) we can obtain the monetary union's aggregate supply:

$$y^s = -\lambda(\varepsilon - 1)p - \lambda\varepsilon\mu(e_{\text{W}} + p^* - p) - \lambda z + \lambda v + \lambda t + l + prod$$

where $\lambda = \frac{1}{\eta + \varphi}$.

To simplify, we group all the exogenous supply shocks in a contractionary disturbance s:

$$s = z - v - \tfrac{1}{\lambda}l - \tfrac{1}{\lambda}prod$$

where s embodies the negative effect on output of an increase in the degree of wage pressure, z; and the positive effects of increases in the expectations errors, v; active population, l; and productivity, $prod$.

Then, the aggregate supply of the union will be:

$$y^s = -\lambda(\varepsilon - 1)p - \lambda\varepsilon\mu(e_{\text{W}} + p^* - p) - \lambda s + \lambda t \tag{15}$$

and, in a similar way, for the rest of the world:

$$y^{*s} = -\lambda(\varepsilon - 1)p^* + \lambda\varepsilon\mu(e_{\text{W}} + p^* - p) - \lambda s^* \tag{16}$$

where:

$$s^* = z^* - v^* - t^* - \tfrac{1}{\lambda}l^* - \tfrac{1}{\lambda}prod^*$$

2.1 The countries of the union

In order to study the interaction between the member countries of the monetary union and the extent to which authorities can deal with shocks using supply-side policies, we need to know the economic framework of the member countries 1 and 2.

The set of equations for country 1 is the following:

$$y_1 = -\alpha r_{\mathrm{W}} + \gamma g_1 + \beta(e_{\mathrm{W}} + p^* - p_1) + \beta(p_2 - p_1)$$

$$+\delta y^* + \delta(y_2 - y_1) + f_1 \tag{17}$$

$$p_{c1} = \frac{(1-\mu)}{2} p_1 + \frac{(1-\mu)}{2} p_2 + \mu(p^* + e_{\mathrm{W}}) \tag{18}$$

$$w_1 - \varepsilon p_{c_1} = \phi prod_1 - \eta u_1 + z_1 - v_1 - t_1 \tag{19}$$

$$p_1 - w_1 = -\phi prod_1 - \varphi u_1 \tag{20}$$

$$y_1^s = n_1 + prod_1 \tag{21}$$

We assume that coefficient β is the same for both the price differential between the union's countries (notice that nominal exchange rate disappears in this case), and the real exchange rate between the union and the rest of the world. In a similar way, we coefficient δ is assumed to be the same for the output of country 2 and the output of the rest of the world. Different assumptions would not change the basic results.

The equations for country 2 would be symmetric:

$$y_2 = -\alpha r_{\mathrm{W}} + \gamma g_2 + \beta(e_{\mathrm{W}} + p^* - p_2) + \beta(p_1 - p_2)$$

$$+\delta y^* + \delta(y_1 - y_2) + f_2 \tag{22}$$

$$p_{c2} = \frac{(1-\mu)}{2} p_1 + \frac{(1-\mu)}{2} p_2 + \mu(p^* + e_{\mathrm{W}}) \tag{23}$$

$$w_2 - \varepsilon p_{c2} = \phi prod_2 - \eta u_2 + z_2 - v_2 - t_2 \tag{24}$$

$$p_2 - w_2 = -\phi prod_2 - \varphi u_2 \tag{25}$$

$$y_2^s = n_2 + prod_2 \tag{26}$$

On the other hand, the money market equilibrium condition -equation (2)- is common to the two countries. We can rewrite it as follows:

$$m - \frac{1}{2}p_1 - \frac{1}{2}p_2 = \frac{\theta}{2}y_1 + \frac{\theta}{2}y_2 - \psi r_{\mathrm{W}} \tag{27}$$

Notice that, since all the variables are in rates of change, the variables of the monetary union are equal to the weighted sum of the member countries' variables, and we can assume that their relative weights reflect the bargaining power of each country inside the union. That is, for any variable x:

$$x = \frac{Y_1}{Y}x_1 + \frac{Y_2}{Y}x_2$$

where x, x_1, x_2 are the rates of change of each variable for the union, country 1, and country 2 respectively; Y, Y_1, Y_2 are their levels of output, and $Y_1 + Y_2 = Y$. For convenience, we have assumed $\frac{Y_1}{Y} = \frac{Y_2}{Y} = \frac{1}{2}$. So, from the weighted sum of equations (17) to (21) and (22) to (26), we can obtain equations (1), and (3) to (6) for the monetary union.

2.2 The transmission of the shocks

From equations (1) to (6) and (7) to (12), and assuming equilibrium in the goods market: $y^s = y^d = y$ and $y^{*s} = y^{*d} = y^*$, we can obtain the reduced forms for the monetary union and the rest of the world (see Appendix A.I).

$$y = a_y m \pm b_y m^* + c_y g + d_y f \pm h_y f^* - i_y s - j_y s^* + i_y t \tag{28}$$

$$y^* = a_y m^* \pm b_y m \pm k_y g + d_y f^* \pm h_y f - i_y s^* - j_y s + j_y t \tag{29}$$

$$p = a_p m \pm b_p m^* + c_p g + d_p f + h_p f^* + i_p s + j_p s^* - i_p t \tag{30}$$

$$p^* = a_p m^* \pm b_p m + k_p g + d_p f^* + h_p f + i_p s^* + j_p s - j_p t \tag{31}$$

Equations (28) to (31) show the interdependence between the two economies, given by the interaction of the variables. On the other hand, if the variables of the monetary union are equal to the weighted sum of the member countries' variables, and the interaction taking place between them is equivalent to the interaction between the union and the rest of the world, we could rewrite the preceding equations as follows (see Appendix A.I):

$$y_1 = a_y m \pm b_y^{'} m^* + c_y^{'} g_1 \pm c_y^{''} g_2 + d_y^{'} f_1 \pm d_y^{''} f_2$$

$$\pm h_y^{'} f^* - i_y^{'} s_1 - i_y^{''} s_2 - j_y^{'} s^* + i_y^{'} t_1 + i_y^{''} t_2 \tag{32}$$

$$y_2 = a_y m \pm b_y^{''} m^* + c_y^{'} g_2 \pm c_y^{''} g_1 + d_y^{'} f_2 \pm d_y^{''} f_1$$

$$\pm h_y^{''} f^* - i_y^{'} s_2 - i_y^{''} s_1 - j_y^{''} s^* + i_y^{'} t_2 + i_y^{''} t_1 \tag{33}$$

$$y^* = a_y m^* \pm b_y m \pm k_y^{'} g_1 \pm k_y^{''} g_2 + d_y f^*$$

$$\pm h_y^{'} f_1 \pm h_y^{''} f_2 - i_y s^* - j_y^{'} s_1 - j_y^{''} s_2 + j_y^{'} t_1 + j_y^{''} t_2 \tag{34}$$

$$p_1 = a_p m \pm b_p^{'} m^* + c_p^{'} g_1 + c_p^{''} g_2 + d_p^{'} f_1 + d_p^{''} f_2$$

$$+ h_p^{'} f^* + i_p^{'} s_1 + i_p^{''} s_2 + j_p^{'} s^* - i_p^{'} t_1 - i_p^{''} t_2 \tag{35}$$

$$p_2 = a_p m \pm b_p^{''} m^* + c_p^{'} g_2 + c_p^{''} g_1 + d_p^{'} f_2 + d_p^{''} f_1$$

$$+ h_p^{''} f^* + i_p^{'} s_2 + i_p^{''} s_1 + j_p^{''} s^* - i_p^{'} t_2 - i_p^{''} t_1 \tag{36}$$

$$p^* = a_p m^* \pm b_p m + k_p^{'} g_1 + k_p^{''} g_2 + d_p f^*$$

$$+h_p^{'}f_1 + h_p^{''}f_2 + i_p s^* + j_p^{'}s_1 + j_p^{''}s_2 - j_p^{'}t_1 - j_p^{''}t_2 \tag{37}$$

The reduced form given by equations (32) to (37) shows the interaction among the two countries of the union and the rest of the world.

Notice that we have two kinds of monetary shocks: the monetary policy instrument of the union monetary authority (m) and monetary shocks from the rest of the world (m^*). On the other hand, regarding real and supply shocks, we can observe shocks from both the union's countries (f_1,f_2,s_1,s_2), and the rest of the world (f^*, s^*).

2.2.1 Supply shocks

Solving the model, we find that a negative supply shock affecting one of the countries of the union (s_1, $s_2 > 0$) or the rest of the world ($s^* > 0$), leads to an output fall and a rise in prices; both in the union and in the rest of the world. This effect is independent of the channel of transmission and the origin of the shock.

Regarding the institutional supply variables of the union's member countries (t_1, t_2), their effects have the same absolute value but the opposite sign as compared to the supply shocks.

The supply shocks multipliers are as follows:

$$\frac{\partial y_1}{\partial s_1} = \frac{\partial y_2}{\partial s_2} = -\frac{\partial y_1}{\partial t_1} = -\frac{\partial y_2}{\partial t_2} = -i_y^{'} \tag{38}$$

$$\frac{\partial y_1}{\partial s_2} = \frac{\partial y_2}{\partial s_1} = -\frac{\partial y_1}{\partial t_2} = -\frac{\partial y_2}{\partial t_1} = -i_y^{''} \tag{39}$$

$$\frac{\partial y_1}{\partial s^*} = \frac{\partial y^*}{\partial s_1} = -\frac{\partial y^*}{\partial t_1} = -j_y^{'} \tag{40}$$

$$\frac{\partial y_2}{\partial s^*} = \frac{\partial y^*}{\partial s_2} = -\frac{\partial y^*}{\partial t_2} = -j_y^{''} \tag{41}$$

$$\frac{\partial y^*}{\partial s^*} = -i_y \tag{42}$$

$$\frac{\partial p_1}{\partial s_1} = \frac{\partial p_2}{\partial s_2} = -\frac{\partial p_1}{\partial t_1} = -\frac{\partial p_2}{\partial t_2} = i_p^{'} \tag{43}$$

$$\frac{\partial p_1}{\partial s_2} = \frac{\partial p_2}{\partial s_1} = -\frac{\partial p_1}{\partial t_2} = -\frac{\partial p_2}{\partial t_1} = i_p^{''} \tag{44}$$

$$\frac{\partial p_1}{\partial s^*} = \frac{\partial p^*}{\partial s_1} = -\frac{\partial p^*}{\partial t_1} = j_p^{'} \tag{45}$$

$$\frac{\partial p_2}{\partial s^*} = \frac{\partial p^*}{\partial s_2} = -\frac{\partial p^*}{\partial t_2} = j_p^{''} \tag{46}$$

$$\frac{\partial p^*}{\partial s^*} = i_p \tag{47}$$

2.2.2 Demand shocks

Positive demand shocks (m, m^*, g_1, g_2, f_1, f_2, $f^* > 0$) lead to positive effects in the output and prices of the country of origin of the shock. But when the shock is transmitted between the countries of the union, and between every member country and the rest of the world, the sign of the coefficients depends on which channel of transmission prevails.

In our model, the channels of transmission of the demand shocks are the aggregate demand, the interest rate, the real exchange rate between the union and the rest of the world, and the monetary union's relative prices. When aggregate demand prevails, the result is the "*locomotive effect*": the effects on the output and prices of the country of origin of the shock are transmitted to the rest of the economies with the same sign. But when changes in the interest rate and the real exchange rate prevail, the result is the "*beggar-thy-neighbour effect*": the effects on the output and prices of the country of origin of the shock are transmitted to the rest of the economies with the opposite sign. The reason is that a real exchange rate depreciation (appreciation) in an economy leads to an aggregate demand expansion (contraction) in that economy, and to a contraction (expansion) in the other, given that which means a depreciation (appreciation) for an economy, means an appreciation (depreciation) for the other.

The "*locomotive effect*" An increase in the money supply ($m, m^* > 0$) -positive monetary shocks, in general- , and positive real shocks (f_1, f_2, $f^* > 0$) lead to an increase in output. The result is an aggregate demand expansion with an output expansion an a rise in prices in all the involved economies.

The money supply multipliers are as follows:

$$\frac{\partial y_1}{\partial m} = \frac{\partial y_2}{\partial m} = \frac{\partial y^*}{\partial m^*} = a_y \tag{48}$$

$$\frac{\partial y_1}{\partial m^*} = b_y^{'} \text{ and } \frac{\partial y_2}{\partial m^*} = b_y^{''} \tag{49}$$

$$\frac{\partial y^*}{\partial m} = b_y \tag{50}$$

$$\frac{\partial p_1}{\partial m} = \frac{\partial p_2}{\partial m} = \frac{\partial p^*}{\partial m^*} = a_p \tag{51}$$

$$\frac{\partial p_1}{\partial m^*} = b_p^{'} \text{ and } \frac{\partial p_2}{\partial m^*} = b_p^{''} \tag{52}$$

$$\frac{\partial p^*}{\partial m} = b_p \tag{53}$$

and the multipliers of the real shocks:

$$\frac{\partial y_1}{\partial f_1} = \frac{\partial y_2}{\partial f_2} = d_y^{'} \text{ and } \frac{\partial y_1}{\partial f_2} = \frac{\partial y_2}{\partial f_1} = d_y^{''} \tag{54}$$

$$\frac{\partial y_1}{\partial f^*} = \frac{\partial y^*}{\partial f_1} = h_y^{'} \text{ and } \frac{\partial y_2}{\partial f^*} = \frac{\partial y^*}{\partial f_2} = h_y^{''} \tag{55}$$

$$\frac{\partial y^*}{\partial f^*} = d_y \tag{56}$$

$$\frac{\partial p_1}{\partial f_1} = \frac{\partial p_2}{\partial f_2} = d_p^{'} \text{ and } \frac{\partial p_1}{\partial f_2} = \frac{\partial p_2}{\partial f_1} = d_p^{''} \tag{57}$$

$$\frac{\partial p_1}{\partial f^*} = \frac{\partial p^*}{\partial f_1} = h_p^{'} \text{ and } \frac{\partial p_2}{\partial f^*} = \frac{\partial p^*}{\partial f_2} = h_p^{''} \tag{58}$$

$$\frac{\partial p^*}{\partial f^*} = d_p \tag{59}$$

The "*beggar-thy-neighbour effect*" An increase in the money supply of the monetary union ($m > 0$), increases output and leads to an exchange rate depreciation between the monetary union and the rest of the world. The result is the "*beggar-thy-neighbour effect*": the monetary union's output and prices rise, but output and prices fall in the rest of the world. The case of a positive money supply shock from the rest of the world ($m^* > 0$) to the monetary union, would be symmetric.

The multipliers that differ with respect to the "*locomotive effect*" case above are the following:

$$\frac{\partial y_1}{\partial m^*} = -b_y^{'} \text{ and } \frac{\partial y_2}{\partial m^*} = -b_y^{''} \tag{60}$$

$$\frac{\partial y^*}{\partial m} = -b_y \tag{61}$$

$$\frac{\partial p_1}{\partial m^*} = -b_p^{'} \text{ and } \frac{\partial p_2}{\partial m^*} = -b_p^{''} \tag{62}$$

$$\frac{\partial p^*}{\partial m} = -b_p \tag{63}$$

Regarding real disturbances, positive shocks to the monetary union (f_1, $f_2 > 0$) lead to an expansion in aggregate demand that is partially offset by a real exchange rate appreciation. This appreciation reduces aggregate supply in the rest of the world, which translates to the union's member countries. The result is that the output of the country suffering the shock rises, and the output of the other country and the rest of the world fall, with prices always rising. The case of a positive real shock from the rest of the world ($f^* > 0$) would be symmetric.

The multipliers that differ with respect to the "*locomotive effect*" case above are now the following:

$$\frac{\partial y_1}{\partial f_2} = \frac{\partial y_2}{\partial f_1} = -d_y^{''} \tag{64}$$

$$\frac{\partial y_1}{\partial f^*} = \frac{\partial y^*}{\partial f_1} = -h_y^{'} \text{ and } \frac{\partial y_2}{\partial f^*} = \frac{\partial y^*}{\partial f_2} = -h_y^{''} \tag{65}$$

3 Supply policy coordination in a monetary union

In the previous section we have studied the transmission of macroeconomic disturbances affecting interdependent economies, and the extent to which supply-side policies adopted by the member countries' governments in a monetary union, generates disturbances in the rest of the world. The purpose of this section is to show how international policy coordination may internalize these spillover effects. The theoretical arguments supporting policy coordination are based on the idea that cooperation internalizes the effects of economic interdependence. In this context we need to take into account the strategic behaviour of the authorities, so we will use the Game Theory approach in order to study how the authorities can deal with shocks.

3.1 The preferences of the countries

We assume that countries 1 and 2 are represented by their authorities, which face the problem of minimizing their loss functions:

$$L_1 = y_1^2 + \sigma_1 g_1^2 \tag{66}$$

$$L_2 = y_2^2 + \sigma_2 g_2^2 \tag{67}$$

where the target variables are the rates of change in output (y_1, y_2), and in the budget deficit (g_1, g_2). For this purpose, the authorities will use as a policy instrument an institutional variable (t_1, t_2),affecting the process of wage setting. The parameters $\sigma_1, \sigma_2 > 0$ are the inverse of the marginal substitution rates, i.e., the cost of reaching an objective relative to the cost of reaching the other. On the other hand, the quadratic form of the loss function implies that any change, positive or negative, in the variables will represent a loss of utility. So, each country will minimize its loss function when all the objectives become equal to zero: $y_1 = y_2 = 0$ and $g_1 = g_2 = 0$.

We are modelling a monetary union where the monetary authority (a common central bank) controls the price target, so the latter has not been included in the loss function of the member countries' authorities. However, the fact that the disciplining effects of a monetary union imply some restrictions on the budget deficit, leads us to include this as an objective of the authorities. An example of this situation is the European monetary union, where each member country will have to consider the requirements imposed by the Pact for Stability and Growth.

Alternatively, if we would have assumed that the member countries' authorities do not delegate completely prices control to the common central bank, their loss function would be:

$$L_i = y_i^2 + \sigma_i g_i^2 + \pi_i p_i^2 \qquad i = 1, 2$$

It can be proved (see Appendix A.II) that the results only differ from the case analysed in this paper (fiscal restrictions and full delegation) in the size of the coefficients. In particular, the desirability of delegating the control of prices depends on the effects of the shock on the economy and the use of the institutional variable as instrument.

In an attempt to describe more accurately the EMU, in the rest of the paper, we will make use of the loss functions represented by equations (66) and (67).

3.2 The optimization problem

In this subsection we will show the effects of the authorities' decisions when coping with shocks. For this reason, we will analyse how they will react when facing shocks that affect both the money market (m, m^*) and the goods market (f_1, f_2, f^*), shifting the aggregate demand curve; and when facing supply shocks (s_1, s_2, s^*), which shift the aggregate supply curve.

Each country of the monetary union has to minimize its loss function by choosing the optimal rate of change of the institutional variable, subject to the restrictions imposed by the international economic framework. According to the Game Theory literature, there are three possibilities to solve the problem: the competitive equilibrium, the leader-follower model, and the cooperative solution. But the solutions will depend on the prevailing channel of transmission: the aggregate demand, or the interest rate and the real exchange rate. So, we will solve the problem for these two alternative cases.

3.3 The "*locomotive effect*"

When aggregate demand is the prevailing channel of transmission, the restrictions that governments have to take into account when solving their optimization problem are as follows:

$$y_1 = a_y m + b_y^{'} m^* + c_y^{'} g_1 + c_y^{''} g_2 + d_y^{'} f_1 + d_y^{''} f_2 + h_y^{'} f^*$$

$$-i_y^{'} s_1 - i_y^{''} s_2 - j_y^{'} s^* + i_y^{'} t_1 + i_y^{''} t_2 \tag{68}$$

$$y_2 = a_y m + b_y^{''} m^* + c_y^{'} g_2 + c_y^{''} g_1 + d_y^{'} f_2 + d_y^{''} f_1 + h_y^{''} f^*$$

$$-i_y^{'} s_2 - i_y^{''} s_1 - j_y^{''} s^* + i_y^{'} t_2 + i_y^{''} t_1 \tag{69}$$

3.3.1 Non-cooperative solution: The competitive solution

When each country solves the problem individually, ignoring interdependence and taking as given the other country's policy, the solution is the Nash-Cournot Equilibrium. The optimization problem of country 1 is as follows:

$$\min_{t_1} L_1 = y_1^2 + \sigma_1 g_1^2 \quad s.t.(68) \tag{70}$$

From the first-order condition we obtain the reaction function of country 1, which shows the response to shocks and to changes in the country 2's policy (see Appendix A.III):

$$t_{R,1} = -R_1 t_2 - R_2 g_1 - R_3 g_2 - R_4 f_1 - R_5 f_2 - R_{1,6} f^* - R_7 m - R_{1,8} m^*$$

$$+s_1 + R_1 s_2 + R_{1,9} s^* \tag{71}$$

The problem for country 2 is similar:

$$\min_{t_2} L_2 = y_2^2 + \sigma_2 g_2^2 \tag{72}$$

$$s.t.(69)$$

from which we obtain:

$$t_{R,2} = -R_1 t_1 - R_2 g_2 - R_3 g_1 - R_4 f_2 - R_5 f_1 - R_{2,6} f^* - R_7 m - R_{2,8} m^*$$

$$+ s_2 + R_1 s_1 + R_{2,9} s^* \tag{73}$$

The absolute value of each coefficient indicates the size of the response to shocks. We can see that when a country suffers a supply shock (s_1 or s_2), the coefficient on the change of the institutional variable has the same size but opposite sign than the shock. When the shock is originated in the own country, its coefficient equals one, so that the use of the institutional variable totally offset the (adverse) effects of the shock. But when a country has to deal with a shock from the other country, the institutional variable changes in a proportion lower than one (since $|R_1| < 1$). Similarly, the rest of the shocks are not totally offset (in other words$|R_i| < 1$ for $i = 2, ..., 9.$), which may indicate that supply-side policies are not the best policies to cope with that kind of shocks.

Both reaction functions have negative slopes. The country 1's reaction function has a slope greater than one in absolute value: $\left.\frac{dt_2}{dt_1}\right|_{t_1=R(t_2)} = -\frac{1}{R_1}$, with $\left|-\frac{1}{R_1}\right| > 1$. This means that any movement along the country 1's reaction function requires a lower change of the institutional variable in country 1 than in country 2. Solving their problems individually, and ignoring interdependence, a country minimization of the changes in its institutional variable requires a greater variation of the other country's variable. We can see from the loss functions -equations (66) and (67)- that any deviation of the target variables from zero, $y_1 \neq y_2 \neq 0$ and $g_1 \neq g_2 \neq 0$, will represent a loss of utility. When a country suffers a shock, the *bliss points* are given by $B_1 = (0, t_2 \neq 0)$ and $B_2 = (t_1 \neq 0, 0)$ which are the origin of the indifference curves. The countries would achieve the maximum welfare in these points because they would not have to change their institutional variables, but conflict emerges since the two points do not coincide.

The Nash-Cournot equilibrium is given by the point where the reaction functions intersect:

$$t_{N,1} = -N_{1,1} g_1 - N_{1,2} g_2 - N_{1,3} f_1 - N_{1,4} f_2 - N_{1,5} f^*$$

$$-N_{1,6} m - N_{1,7} m^* + s_1 + N_{1,8} s^* \tag{74}$$

$$t_{N,2} = -N_{2,1}g_1 - N_{2,2}g_2 - N_{2,3}f_1 - N_{2,4}f_2 - N_{2,5}f^*$$

$$-N_{2,6}m - N_{2,7}m^* + s_2 + N_{2,8}s^* \quad (75)$$

We can see that in the competitive solution each country only offsets the supply shock originated in its own country, but not in the case of a shock originated in the other country. It can be proved (see Appendix A.IV) that the coefficients of the Nash solution are lower, in absolute value, than the coefficients of the reaction function. That is, when solving the problem individually each country acts in a "myopic" way and, since interdependence is ignored, the effects of supply-side policies are transmitted abroad.

3.3.2 Non-cooperative solution: The leader-follower model

When one of the countries acts as a leader and the other as a follower, the result is a Nash-Stackelberg Equilibrium. The leader chooses first taking into account its own interest and the foreign country's reaction function, which the leader includes in its loss function. If country 1 acts as leader, then its optimization problem is given by:

$$\min_{t_1} L_1 = L(y_1, g_1, t_{R,2}) \quad (76)$$

so, it will have to solve:

$$\min_{t_1} L_1 = y_1^2 + \sigma_1 g_1^2 \quad (77)$$

$$s.t.(68), (73)$$

obtaining from the first-order condition:

$$t_{S,1} = \pm S_{1,1}g_1 \pm S_{1,2}g_2 \pm S_{1,3}f_1 \pm S_{1,4}f_2 \pm S_{1,5}f^*$$

$$\pm S_{1,6}m \pm S_{1,7}m^* \pm s_1 \pm S_{1,8}s^* \quad (78)$$

Where it can be seen that the leader only (fully) offset the supply shock originated in its own country.

Taking into account the changes in the leader's institutional variable, the follower solves its optimization problem:

$$\min_{t_2} L_2 = y_2^2 + \sigma_2 g_2^2 \quad s.t.(69),(78) \tag{79}$$

obtaining:

$$t_{S,2} = \pm S_{2,1}g_1 \pm S_{2,2}g_2 \pm S_{2,3}f_1 \pm S_{2,4}f_2 \pm S_{2,5}f^*$$

$$\pm S_{2,6}m \pm S_{2,7}m^* \pm s_2 \pm S_{2,8}s^* \tag{80}$$

It can be proved (see Appendix A.V) that the absolute values in the leader's Stackelberg solution, coincide with the values in the Nash solution. The leader acts in the same "myopic" way than in the competitive solution, and the only shock that is fully offset is the supply shock originated in its own country.

On the other hand, the ambiguity of the signs indicates that the best policy response, expansionary or contractionary, will depend on the value of the coefficients involved in the solution. In any case, the change in the leader's institutional variable is lower than for the follower (see in Appendix A.V that $|S_{1,i}| < |S_{2,i}|$ for $i = 1, ..., 8$). Choosing first, the leader has a time advantage and the follower's response requires a greater change in its variable. Because of that, the Stackelberg equilibrium is not always a Pareto improvement upon the Nash equilibrium. The leader is always better off than in the competitive solution, but the final result for the follower is ambiguous. Moreover, the solution is unstable because the leader is not on its reaction function.

3.3.3 Cooperative solution: The social planner problem

If the countries coordinate their policies, they will minimize the weighted sum of their loss functions. Given the assumption of symmetry, and with the weights of each country equal to $\frac{1}{2}$, the social planner problem would be:

$$\min_{t_1,t_2} \mathfrak{L} = \left[\frac{1}{2}(y_1^2 + \sigma_1 g_1^2) + \frac{1}{2}(y_2^2 + \sigma_2 g_2^2)\right] \quad s.t.(68) \text{ and } (69) \tag{81}$$

From the first-order conditions we obtain (see Appendix A.VI):

$$t_{C,1} = -C_{1,1}g_1 - C_{1,2}g_2 - C_{1,3}f_1 - C_{1,4}f_2 - C_{1,5}f^*$$

$$-C_{1,6}m - C_{1,7}m^* + C_{1,8}s_1 + C_{1,9}s_2 + C_{1,10}s^* \tag{82}$$

$$t_{C,2} = -C_{2,1}g_1 - C_{2,2}g_2 - C_{2,3}f_1 - C_{2,4}f_2 - C_{2,5}f^*$$

$$-C_{2,6}m - C_{2,7}m^* + C_{2,8}s_1 + C_{2,9}s_2 + C_{2,10}s^* \tag{83}$$

3.4 The "*beggar-thy-neighbour effect*"

When the interest rate and the exchange rate are the prevailing channels of transmission, the restrictions that fiscal authorities have to take into account to solve their optimization problem are as follows:

$$y_1 = a_y m - b_y^{'} m^* + c_y^{'} g_1 - c_y^{''} g_2 + d_y^{'} f_1 - d_y^{''} f_2 - h_y^{'} f^*$$

$$-i_y^{'} s_1 - i_y^{''} s_2 - j_y^{'} s^* + i_y^{'} t_1 + i_y^{''} t_2 \tag{84}$$

$$y_2 = a_y m - b_y^{''} m^* + c_y^{'} g_2 - c_y^{''} g_1 + d_y^{'} f_2 - d_y^{''} f_1 - h_y^{''} f^*$$

$$-i_y^{'} s_2 - i_y^{''} s_1 - j_y^{''} s^* + i_y^{'} t_2 + i_y^{''} t_1 \tag{85}$$

3.4.1 Non-cooperative solution: The competitive solution

The Nash-Cournot Equilibrium of country 1 is given by:

$$\min_{t_1} L_1 = y_1^2 + \sigma_1 g_1^2 \quad s.t.(84) \tag{86}$$

and from the first-order conditions we obtain the reaction function (see Appendix A.III):

$$t'_{R,1} = -R'_1 t_2 - R'_2 g_1 + R'_3 g_2 - R'_4 f_1 + R'_5 f_2 + R'_{1,6} f^* - R'_7 m + R'_{1,8} m^*$$

$$+s_1 + R'_1 s_2 + R'_{1,9} s^* \tag{87}$$

The problem is similar for country 2:

$$\min_{t_2} L_2 = y_2^2 + \sigma_2 g_2^2 \tag{88}$$
$$s.t.(85)$$

from which we obtain:

$$t'_{R,2} = -R'_1 t_1 - R'_2 g_2 + R'_3 g_1 - R'_4 f_2 + R'_5 f_1 + R'_{2,6} f^* - R'_7 m + R'_{2,8} m^*$$

$$+s_2 + R'_1 s_1 + R'_{2,9} s^* \tag{89}$$

We can see that in the competitive solution each country only fully offsets the supply shock originated in its own country. And as in the "*locomotive effect*" case, the reaction functions have negative slopes, being the slope of the reaction function of country 1 greater than one. The Nash solution is given by the following equations (see Appendix A.IV):

$$t'_{N,1} = -N'_{1,1} g_1 + N'_{1,2} g_2 - N'_{1,3} f_1 + N'_{1,4} f_2 + N'_{1,5} f^*$$

$$-N'_{1,6} m + N'_{1,7} m^* + s_1 + N'_{1,8} s^* \tag{90}$$

$$t'_{N,2} = N'_{2,1} g_1 - N'_{2,2} g_2 + N'_{2,3} f_1 - N'_{2,4} f_2 + N'_{2,5} f^*$$

$$-N'_{2,6} m + N'_{2,7} m^* + s_2 + N'_{2,8} s^* \tag{91}$$

And again, we can see that in the competitive solution each country only offsets the supply shock originated in its own country, but not in the case of a shock originated in the other country.

3.4.2 Non-cooperative solution: The leader-follower model

Assuming, again, that country 1 acts as the leader, the problem to solve will be:

$$\begin{aligned} \min_{t_1} L_1 &= y_1^2 + \sigma_1 g_1^2 \\ & \quad s.t.(84),(89) \end{aligned} \tag{92}$$

obtaining from the first-order condition:

$$t'_{S,1} = \pm S'_{1,1}g_1 \pm S'_{1,2}g_2 \pm S'_{1,3}f_1 \pm S'_{1,4}f_2 \pm S'_{1,5}f^*$$

$$\pm S'_{1,6}m \pm S'_{1,7}m^* \pm s_1 \pm S'_{1,8}s^* \tag{93}$$

The follower takes this solution into account to solve its own problem:

$$\begin{aligned} \min_{t_2} L_2 &= y_2^2 + \sigma_2 g_2^2 \\ & \quad s.t.(85),(93) \end{aligned} \tag{94}$$

obtaining therefore:

$$t'_{S,2} = \pm S'_{2,1}g_1 \pm S'_{2,2}g_2 \pm S'_{2,3}f_1 \pm S'_{2,4}f_2 \pm S'_{2,5}f^*$$

$$\pm S'_{2,6}m \pm S'_{2,7}m^* \pm s_2 \pm S'_{2,8}s^* \tag{95}$$

In the same way as in the "*locomotive effect*" case, the absolute values in the leader's Stackelberg solution, coincide with the values in the Nash solution. On the other hand, the ambiguity of the signs indicates that the best policy response, expansionary or contractionary, will depend on the value of the involved coefficients. The leader has a time advantage and its institutional variable has to change less, in absolute value, than the follower's variable (see in Appendix A.V that $|S'_{1,i}| < |S'_{2,i}|$ for $i = 1, ..., 8$).

3.4.3 Cooperative solution: The social planner problem

Choosing again weights equal to $\frac{1}{2}$, the problem would be:

$$\begin{aligned}\min_{t_1,t_2} \mathfrak{L} &= \left[\frac{1}{2}(y_1^2+\sigma_1 g_1^2)+\frac{1}{2}(y_2^2+\sigma_2 g_2^2)\right] \\ & s.t.(84) \text{ and } (85) \end{aligned} \quad (96)$$

From the first-order conditions we obtain (see Appendix A.VI):

$$t'_{C,1} = \pm C'_{1,1}g_1 \pm C'_{1,2}g_2 \pm C'_{1,3}f_1 \pm C'_{1,4}f_2 + C'_{1,5}f^*$$

$$-C'_{1,6}m + C'_{1,7}m^* + C'_{1,8}s_1 + C'_{1,9}s_2 + C'_{1,10}s^* \quad (97)$$

$$t'_{C,2} = \pm C'_{2,1}g_1 \pm C'_{2,2}g_2 \pm C'_{2,3}f_1 \pm C'_{2,4}f_2 + C'_{2,5}f^*$$

$$-C'_{2,6}m + C'_{2,7}m^* + C'_{2,8}s_1 + C'_{2,9}s_2 + C'_{2,10}s^* \quad (98)$$

In the "*locomotive effect*" case, the authorities used contractionary supply-side policies when dealing with expansionary shocks, and expansionary supply-side policies when dealing with contractionary shocks. Moreover, both in the competitive solution and in the cooperative solution, the policy's sense (expansionary or contractionary) was the same than in the optimal response given by the reaction function.

But in the "*beggar-thy-neighbour effect*" case, the supply-side policies used to deal whit real shocks from the monetary union has an ambiguous sense. From this result we can conclude that the cooperative solution will not always coincide with the optimal response given by the reaction function. In those cases, the cooperative solution's instability would increase. The reason is that the cooperative solution would not be on the reaction function and, in addition, would not coincide with the optimal individual policy response of each country.

4 Welfare aspects of the optimal solution

Theoretically, the cooperative solution is Pareto improving since it internalizes the spillover effects arising from economic interdependence. These externalities, $\frac{\partial L_1}{\partial t_2}$ and $\frac{\partial L_2}{\partial t_1}$, show how the loss function of a country changes in response to changes in the other country's instrument. For that reason cooperation is Pareto improving, since the competitive solution neglects the externalities produced by changes in the policy instrument.

On the one hand, the first-order conditions from which we have obtained the Nash Equilibrium are $\frac{dL_1}{dt_1} = 0$ and $\frac{dL_2}{dt_2} = 0$. But for these points $\frac{\partial L_1}{\partial t_2} \neq 0$ and $\frac{\partial L_2}{\partial t_1} \neq 0$. On the other hand, the first-order conditions of the social planner problem are:

$$\frac{\partial \mathfrak{L}}{\partial t_1} = \frac{1}{2}\left(\frac{\partial L_1}{\partial t_1} + \frac{\partial L_2}{\partial t_1}\right) = 0 \tag{99}$$

$$\frac{\partial \mathfrak{L}}{\partial t_2} = \frac{1}{2}\left(\frac{\partial L_1}{\partial t_2} + \frac{\partial L_2}{\partial t_2}\right) = 0 \tag{100}$$

From these conditions it is clear that $\frac{\partial L_1}{\partial t_1} = -\frac{\partial L_2}{\partial t_1}$ and $\frac{\partial L_2}{\partial t_2} = -\frac{\partial L_1}{\partial t_2}$, which shows how the cooperative solution internalizes externalities. But the desirability of the cooperative solution will depend on the nature of the externality since, if this externality has the same sign than the shock, the cooperative solution does not offset the adverse effects. Subsequently, we can conclude that cooperation may be counterproductive when it internalizes spillover effects which reinforce the effects of the shock.

In order to avoid the spillover effects of their policies, countries' authorities will try to minimize the use of the institutional variable. In this sense, they identify stabilization with avoiding changes in the policy instrument. In particular, we have modelled a loss function in which any change in the variables implies a loss of utility. Since the target variables are linear in the policy instruments, the solution that requires a lower change in the institutional variable would be the optimal solution. So, in a first step, authorities will minimize their loss function, and, in a second step, they will choose the solution (competitive or cooperative) with the lower absolute value:

$$t = \arg\min \{|t_{N,i}|, |t_{C,i}|\} \ \ \forall i = 1, 2$$

It is difficult to know the size of the coefficients of the solutions, since they depend on the coefficients of the reduced form -equations (32) to (37). For that reason, in order to compare the Nash solution with the cooperative solution we will make use of graphical analysis. We will take into account both the slope of the reaction functions (negative for the "*locomotive effect*" and for the"*beggar-thy-neighbour effect*"), and the sign of the solutions.

4.1 The "*locomotive effect*"

From the reduced form -equations (68) and (69)- we can see that the target variables (y_1, y_2) are linear in the policy instruments (t_1, t_2). Because of that, we can plot both the reaction functions and the indifference curves in the same $t_1 - t_2$ plane. For simplicity, we will not show the indifference curves. As can be seen from the graphs, the reaction functions have negative slopes. Figure 1 shows that the reaction functions intersect at the origin: none of the countries has to change its institutional variable in that point, since there are no shocks. If any disturbance takes place, the reaction functions would shift to the left or to the right according to the particular type of shock.

Figure 2 shows the reaction functions after an expansionary shock in any of the countries. In these cases, the authorities find optimal a contractive policy to offset the effects of the shock. So, the reaction functions shift to the left. Equations (68) and (69) show that output expands following expansionary demand shocks $(m, m^*, f_1, f_2,\ f^* > 0)$,expansionary supply shocks originated simultaneously in the monetary union ($s_1 < 0$ and $s_2 < 0$ together), or expansionary supply shocks originated in the rest of the world ($s^* < 0$). So that, *bliss points* for countries 1 and 2 are at points $B_1 = (0, t_2 < 0)$ and $B_2 = (t_1 < 0, 0)$ respectively.

The Nash solution is at point N in Figure 2, where the reaction functions intersect. Cooperative solutions will be on the contract curve, which, by linking B_1 and B_2, captures Pareto efficient combinations along the tangencies between the indifference curves. There are infinite cooperative solutions, but we can focus on the case in which both countries react in the

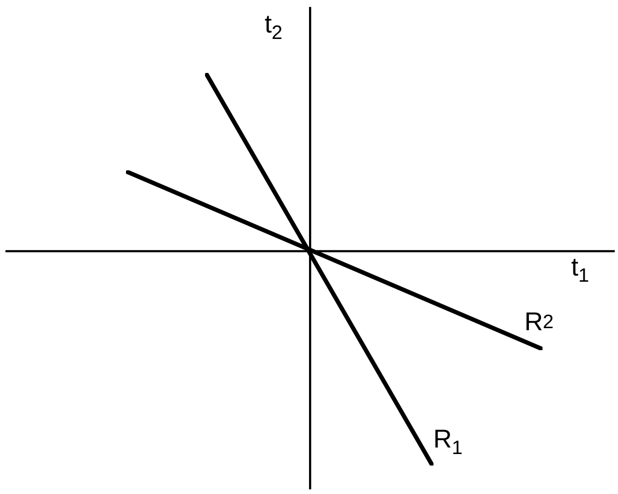

Figure 1: Reaction functions in absence of shocks.

same way, $t_1 = t_2$. In a symmetric model, with the same bargaining weights for each country, it is reasonable to assume that the gains and losses from cooperation would be divided equally. In that case, the solution -which is the most symmetric possible- is given by point C in Figure 2.But, in any case, cooperative solutions require a greater change in the institutional variable than the Nash solution, so that cooperation is counterproductive.

If we depict the case of a contractionary shock leading to a recession in both countries, the reaction functions shift to the right (see Figure 3). The Nash solution is at point N in Figure 3, where the reaction functions intersect, and the cooperative symmetric case, point C, requires a greater change in the institutional variable than the Nash solution. Hence, cooperation is counterproductive again.

On the other hand, we can see from reaction functions -equations (71) and (73)- that when a supply shock has its origin in one of the monetary union's member countries (i.e., $s_1 \neq 0$ or $s_2 \neq 0$, but not simultaneously), the movement is greater for the reaction function of the country where the shock has its origin. In Figure 4 we depict the case of a contractionary supply shock in country 1 ($s_1 > 0$). Now, *bliss points* are $B_1 = (0, t_2 > 0)$ and $B_2 = (t_1 > 0, 0)$, and the competitive solution is given by point N where the

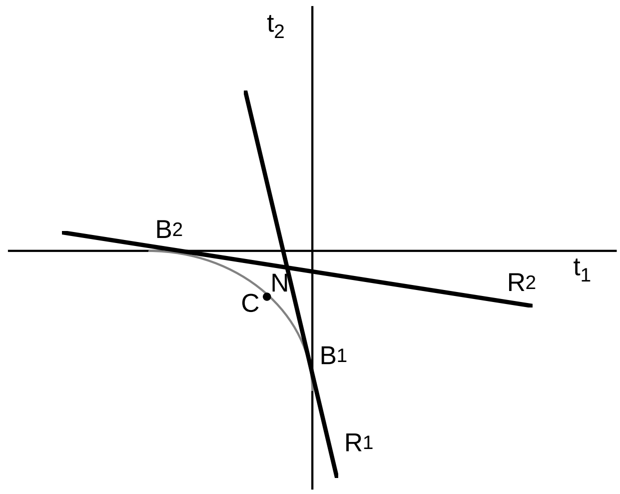

Figure 2: Expansionary shock in both countries. Cooperation counterproductive.

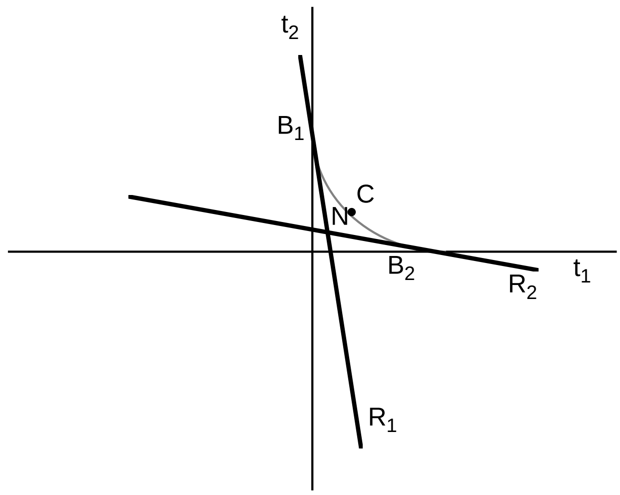

Figure 3: Contractionary shock in both countries. Cooperation counterproductive.

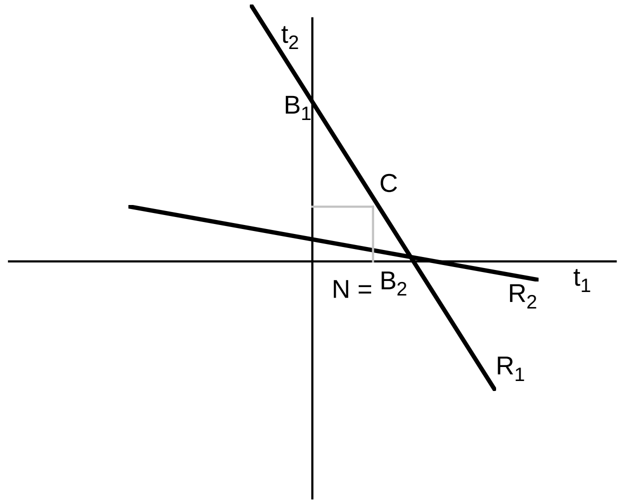

Figure 4: Contractionary shock in country 1. Cooperation useful for country 1 and counterproductive for country 2.

reaction functions intersect. This point $N = (t_1 > 0, 0)$ coincides with B_2. The cooperative solution is along the line linking B_1 and B_2, and coincides with a segment of the country 1's reaction function. In this particular case, cooperation is useful for country 1 but counterproductive for country 2, which has not suffered the shock. The reason is that along the line linking B_1 and B_2, changes in country 1's institutional variable are lower than when country 1 acts individually. C represents the symmetric cooperative solution.

We have just shown that, when aggregate demand is the channel of transmission of the shocks, supply-side policy coordination in a monetary union would result counterproductive for the union member countries, when they cope with demand shocks in general. When dealing with supply shocks, cooperation would be counterproductive if the shock has its origin in the rest of the world. But for supply shocks within the monetary union, cooperation would be useful, but only for the country where the shock has its origin.

In the previous section it was shown that the cooperative solution internalizes externalities that are different from zero. When the externality has the same sign than the shock, the cooperative solution reinforces the adverse effects of the shock. It can be proved for the "*locomotive effect*" (see Appendix VII), that for positive shocks externalities are also positive, and for negative shocks externalities are negative. For that reason cooperation is counterproductive, since it internalizes externalities that reinforce the effect of the shock and requires a greater change in the institutional variable. So, in order to avoid some of the adverse effects, it would be preferable not to coordinate.

4.2 The "*beggar-thy-neighbour effect*"

For the "*beggar-thy-neighbour effect*", the reaction functions have also negative slopes. So, the case of absence of shocks is depicted in Figure 1 again.

When changes in the interest rate and in the exchange rate are the prevailing channel of transmission, expansionary (contractionary) real shocks in a country translate into a contraction (expansion) to the other country ($f_1 > 0, f_2 < 0$ or $f_1 < 0, f_2 > 0$). When the output of a country expands, the output of the other falls (see equations (84) and (85)). Figure 5 and Figure 6 show the alternative possibilities. In both cases, cooperation results useful since cooperative solutions (cooperative symmetric case given by point C) require a lower change in the institutional variable as compared to the Nash solution (point N).

On the other hand, when shocks expand the output of both countries; i.e., positive monetary and supply shocks from the union ($m > 0$ or $s_{1,}s_2 < 0$ simultaneously), or contractive demand shocks and positive supply shocks from the rest of the world ($m^*, f^*, s^* < 0$), reaction functions shift to the left in both countries. In those cases, since cooperative solution requires a grater change in the institutional variable, cooperation is counterproductive (see point C in Figure 2).

The same result is obtained for a recession in both countries (see Figure 3).

It can be proved that for the "*beggar-thy-neighbour effect*" (see Appendix A.VII) in the case of real shocks from the union (f_1, f_2) externalities have the opposite sign than the shock (see equations (84) and (85)). Because of that, cooperation is useful since it offsets the effects of the shock and requires a lower change in the institutional variable. But for the rest of shocks (i.e.,

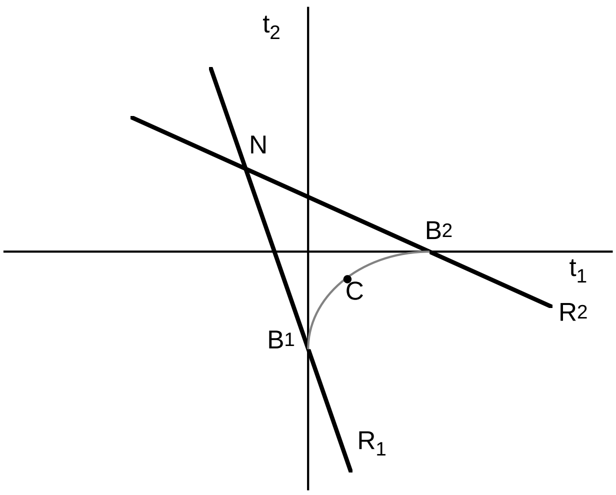

Figure 5: Expansionary real shock in country 1. Cooperation useful.

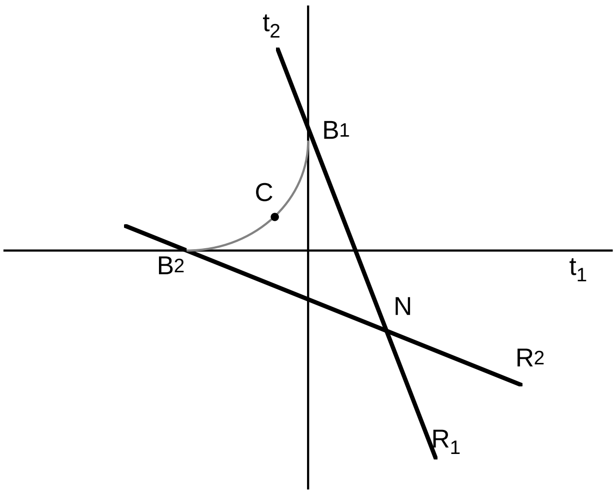

Figure 6: Expansionary real shock in country 2. Cooperation useful.

monetary and supply shocks from the union (m, s_1, s_2) and any shock from the rest of the world (m^*, f^*, s^*)), externalities have the same sign. In those cases, the cooperative solution reinforces the adverse effects, so cooperation results counterproductive.

4.3 The desirability of supply policy coordination

From the results obtained in the previous subsections, we can establish a comparison between the Nash solution and the Cooperative solution. This comparison is shown in Table 4.1, where we provide the effect (expansionary, contractionary, ambiguous or zero) of supply policies used to cope with shocks, depending on the channel of transmission of the shocks.

TABLE 4.1

SUPPLY POLICY FROM THE COUNTRY 1 (SYMMETRIC FOR COUNTRY 2)

	"LOCOMOTIVE"			"BEGGAR-THY-NEIGHBOUR"		
Nature of the shock	R	N	C	R	N	C
m	-	-	-	-	-	-
m^*	-	-	-	+	+	+
f_1, f_2	-,–	-,-	-,-	-,+	-,+	±,±
f^*	-	-	-	+	+	+
s_1, s_2	+,+	+,0	+,+	+,+	+,0	+,+
s^*	+	+	+	+	+	+

Notes: a) R,N and C denote reaction function, Nash solution and Cooperative solution, respectively.
b) (+),(-), (±) and 0 denote the sign of the policy.

Summarising the results obtained, we could derive the conditions under which coordination of supply policies may be useful. These conditions are presented in Table 4.2. From Table 4.2 we can conclude that the results are determined not only by the asymmetry of the shock, but by its nature (monetary, real or supply). When facing monetary shocks, cooperation always results indifferent. But when dealing with real and supply shocks, the channel of transmission proves to be determinant.

TABLE 4.2

DESIRABILITY OF SUPPLY POLICY COORDINATION

SHOCK	COOPERATION
Monetary (m, m^*)	Counterproductive.
Real (f_1, f_2, f^*)	• "Locomotive effect": counterproductive. • "Beggar-thy-neighbour effect": useful when the shock has its origin within the monetary union, and counterproductive for the rest of the cases.
Supply (s_1, s_2, s^*)	Counterproductive.

5 Conclusions

In this paper we have tried to examine how the member countries of a monetary union can deal with asymmetric shocks using coordinated supply-side policies, in absence of monetary policy and suffering restrictions in the use of fiscal policy. In order to offset the effects of the shocks and to maintain the rate of change in output and in the budget deficit, the authorities will use as a policy instrument an institutional variable. In principle, this variable could affect both the degree of price and wage flexibility, and the wage setting process, but could also be interpreted as a way of harmonization of labour market institutions.

We have developed a three-country model in which countries show different preferences regarding objectives, and face asymmetric shocks. Two of the countries form a monetary union where an independent central bank controls monetary policy. As an original contribution, the model has been explicitly designed for a "big" monetary union (i.e., we treat variables from the rest of the world as endogenous).

Since the authorities will have to choose the optimal change in the institutional variable of each country taking into account the spillover effects of supply policies, we have used the Game Theory approach to analyse the authorities' strategic behaviour.

In our model, supply shocks have unambiguous effects on endogenous variables. On the contrary, the effects of demand shocks will depend on the channel of transmission: when aggregate demand prevails, the result is the "*locomotive effect*", whereas if changes in the interest rate and the real exchange rate prevail, the result is the "*beggar-thy-neighbour effect*".

After analysing the solutions for the two alternatives, we can conclude that:

a) For the "*locomotive effect*" case, if the authorities act individually, the solution requires a lower change in the institutional variable than if they coordinate. This result holds for real and monetary shocks, independently of the origin of the shock (the monetary union or the rest of the world). The reason is that the use of the institutional variable as a policy instrument, leads to externalities with the same sign than the shock. In these cases, cooperation would be counterproductive because it would reinforce the effects of the disturbance when internalizing externalities.

For supply shocks, supply policy coordination would result counterproductive when shocks have its origin in either the two countries of the monetary union simultaneously, or in the rest of the world. But when the shock has its origin in only one of the countries of the monetary union, cooperation would be useful but only for the country where the shock appears. In this case, cooperation would be also counterproductive in general terms; in other words, this situation would not be Pareto-optimal.

b) For the "*beggar-thy-neighbour*" case, for all the shocks from the rest of the world, as well as monetary shocks originated in the union, externalities have the same sign than shocks. In those cases, the cooperative solution requires a greater change in the institutional variable than competitive solution; then, cooperation would be counterproductive, since it would reinforce the effects of the shock when internalizing externalities. But for supply shocks from the monetary union, we obtain the same result than in the "*locomotive effect*" case: when the shock has its origin in only one of the countries of the monetary union, cooperation would be useful only for the country where the shock appears.

On the contrary, for real shocks from the monetary union cooperation would be useful since externalities have the opposite sign than the shocks. In those cases, the cooperative solution requires a lower change in the institutional variable than competitive solution.

To summarize, we can conclude that, if the monetary union's authorities include the budget deficit as an objective in their loss function, supply policy coordination would be useful only when changes in the interest rate and the real exchange rate prevail as the channel of transmission; and also when the probability of suffering from real shocks originated within the union is higher. In Díaz (1998), we can find the opposite results for fiscal policy coordination: coordination is useful only when changes in the interest rate and the real exchange rate prevail as the channel of transmission; and also if the probability of suffering from monetary and supply shocks originated in the union, and any kind of shock from the rest of the world, is higher.

As can be seen from the results, the asymmetry of the shocks to deal with is not the only relevant characteristic when deciding to coordinate economic policies: the nature and the origin of the shocks will be also determinant, since the desirability of policies coordination is related to the type of shocks affecting the countries. For this reason, it would be crucial to know which would be the channel of transmission and the kind of disturbances actually prevailing in the monetary union. Regarding this issue, it would be interesting also to take into account that in Viñals and Jimeno (1996) supply policies are proposed as a way to deal with real (symmetric or asymmetric shocks) in a monetary union. According to our results, if real asymmetric shocks from the monetary union prevail, and their effects are transmitted leading to the "*beggar-thy-neighbour*" effect, the desirability of supply policy coordination would be greater than in the rest of the cases.

6 Appendix

A. I The reduced form (Equations 28 to 31)

From equation (2) in the main text, we obtain the equilibrium output in the money market. Next, we substitute it into the goods market equilibrium condition (equation (1)). Doing the same for the equations for the rest of the world , and substracting, we obtain the real exchange rate between the monetary union and the rest of the world:

$$(e_{\mathrm{W}} + p^{*} - p) = \frac{(m-p) - (m^{*} - p^{*}) - \delta\theta(y - y^{*}) - \theta(f - f^{*}) - \theta\gamma g}{2\beta\theta} \quad \text{(A.1)}$$

Replacing (A.1) and the world interest rate, r_{w}, from equation (2) into equation (1) we obtain:

$$y = a_1 m - a_1 p - a_2 m^* + a_2 p^* + a_3 y^* + a_4 f + a_4 f^* + a_5 g \tag{A.2}$$

and also for the rest of the world:

$$y^* = a_1 m^* - a_1 p^* - a_2 m + a_2 p + a_3 y + a_4 f^* + a_4 f + a_5 g \tag{A.3}$$

Then, substituting (A.1) into the aggregate demand and aggregate supply -equations (15) and (16) - we can obtain the following expressions:

$$p = a_6 m + a_6 p^* - a_6 m^* + a_7 y - a_8 y^* - a_9 f + a_9 f^* - a_{10} g + a_{11} s \tag{A.4}$$

$$p^* = a_6 m^* + a_6 p - a_6 m + a_7 y^* - a_8 y - a_9 f^* + a_9 f + a_{10} g + a_{11} s^* \tag{A.5}$$

where:

$$a_1 = \frac{2\theta\alpha+\psi}{\theta(2\psi+2\alpha\theta-\delta\psi)}, \qquad a_2 = \frac{\psi}{\theta(2\psi+2\alpha\theta-\delta\psi)},$$

$$a_3 = \frac{\delta\psi}{2\psi+2\alpha\theta-\delta\psi}, \qquad a_4 = \frac{\psi}{2\psi+2\alpha\theta-\delta\psi},$$

$$a_5 = \gamma a_4, \qquad a_6 = \frac{\lambda\varepsilon\mu}{\lambda\varepsilon\mu+\lambda 2\beta\theta(1-\lambda\varepsilon\mu)},$$

$$a_7 = \frac{(2\beta+\lambda\varepsilon\mu\delta)\theta}{\lambda\varepsilon\mu+\lambda 2\beta\theta(1-\lambda\varepsilon\mu)}, \qquad a_8 = \frac{\delta\theta\lambda\varepsilon\mu}{\lambda\varepsilon\mu+\lambda 2\beta\theta(1-\lambda\varepsilon\mu)},$$

$$a_9 = \frac{\theta\lambda\varepsilon\mu}{\lambda\varepsilon\mu+\lambda 2\beta\theta(1-\lambda\varepsilon\mu)}, \qquad a_{10} = \gamma a_9,$$

$$a_{11} = \frac{2\beta\theta\lambda}{\lambda\varepsilon\mu+\lambda 2\beta\theta(1-\lambda\varepsilon\mu)}$$

To obtain the equilibrium values for output and prices, we need to solve the system given by equations (A.2) to (A.5):

$$\begin{pmatrix} 1 & -a_3 & a_1 & -a_2 \\ -a_3 & 1 & -a_2 & a_1 \\ -a_7 & a_8 & 1 & -a_6 \\ a_8 & -a_7 & -a_6 & 1 \end{pmatrix} \begin{pmatrix} y \\ y^* \\ p \\ p^* \end{pmatrix} = \begin{pmatrix} a_1 m - a_2 m^* + a_4 f + a_4 f^* + a_5 g \\ -a_2 m + a_1 m^* + a_4 f + a_4 f^* + a_5 g \\ a_6 m - a_6 m^* - a_9 f + a_9 f^* - a_{10} g + a_{11} s \\ -a_6 m + a_6 m^* + a_9 f - a_9 f^* + a_{10} g + a_{11} s^* \end{pmatrix}$$

Equations (28) to (31) in the main text are the solution, where the coefficients are:

$$a_y = [a_6(a_1 + a_2)(-1 + a_3 + a_6 - a_7(a_1 - a_2)) + a_1(a_1 a_8 - a_3 a_6 + a_2 a_7) -$$

$$a_2(a_3 + a_2(a_7 + a_8)) + a_1(1 - a_6^2 + a_7(a_1 - a_2 a_6) + a_8(a_2 - a_1 a_6))] \diagup \Delta$$

$$b_y = [a_6(a_1 + a_2)(1 - a_3 - a_6 - a_8(a_1 - a_2)) - a_2(a_1 a_8 - a_3 a_6 + a_2 a_7) +$$

$$a_1(a_3 + a_2 a_7 + a_1 a_8)) - a_2(1 - a_6^2 + a_7(a_1 - a_2 a_6) + a_8(a_2 - a_1 a_6))] \diagup \Delta$$

$$c_y = \gamma d_y$$

$$d_y = [(a_4 + a_5)(1 - a_6^2(1 + a_3) + a_3 + (a_1 + a_2)(a_7 + a_8)(1 - a_6)) +$$

$$(a_9 + a_{10})((a_1 + a_2)(1 - a_6^2(1 + a_3) - a_3 + (a_1 - a_2)(a_7 + a_8)))] \diagup \Delta$$

$$h_y = [(a_4 + a_5)(1 - a_6^2(1 + a_3) + a_3 + (a_1 + a_2)(a_7 + a_8)(1 - a_6)) -$$

$$(a_9 + a_{10})((a_1 + a_2)(1 - a_6^2(1 + a_3) - a_3 + (a_1 - a_2)(a_7 + a_8)))] \diagup \Delta$$

$$i_y = [a_{11}(-a_1(1 + a_3 a_6) - a_7(a_1^2 - a_2^2) + a_2(a_3 + a_6))] \diagup \Delta$$

$$j_y = [a_{11}(a_2(1 + a_3 a_6) - a_8(a_1^2 - a_2^2) - a_1(a_3 + a_6))] \diagup \Delta$$

$$k_y = \gamma h_y$$

$$a_p = [a_6((1 - a_3^2)(1 - a_6) + a_7((1 + a_6)(a_1 - a_2 a_3) + 2a_6(a_1 a_3 - a_2) +$$

$$a_7(a_1^2 - a_2^2) + a_8((1 + a_5)(a_2 - a_1 a_3) + 2a_6(a_2 a_3 - a_1) - a_8(a_1^2 - a_2^2)))] \diagup \Delta$$

$$b_p = [(1-a_6)(a_7(a_1a_3-a_2)+a_8(a_2a_3-a_1)-a_6(1-a_3^2))] \diagup \Delta$$

$$c_p = \gamma d_p$$

$$d_p = [(a_4+a_5)(a_7+a_8)((1+a_3)(1+a_6)+(a_1+a_2)(a_7+a_8))-$$

$$(a_9+a_{10})(1-a_3)((1+a_3)(1-a_6)+(a_1-a_2)(a_7-a_8)] \diagup \Delta$$

$$h_p = [(a_4+a_5)(a_7+a_8)((1+a_3)(1+a_6)+(a_1+a_2)(a_7+a_8))+$$

$$(a_9+a_{10})(1-a_3)((1+a_3)(1-a_6)+(a_1-a_2)(a_7-a_8)] \diagup \Delta$$

$$i_p = [(1-a_3^2)+a_7(a_1-a_2a_3)+a_8(a_2-a_1a_3)] \diagup \Delta$$

$$j_p = [a_6(1-a_3^2)+a_7(a_2-a_1a_3)+a_8(a_1-a_2a_3)] \diagup \Delta$$

$$k_p = \gamma h_p$$

with:

$$\Delta = [1-a_6^2(1-a_3^2)-a_3^2+a_1a_7(2+a_1a_7+2a_3a_6)+a_2a_8(2+a_2a_8+2a_3a_6)$$

$$-a_2a_7(2a_6+a_2a_7+2a_3)-a_1a_8(2a_5+a_1a_8+2a_3)] > 0$$

To obtain equations (32),(33), (35) and (36) from equations (28) and (30) we have assumed that shocks transmit themselves in the same way between the countries of the union and between the union and the rest of the world. As a result, we obtain the reduced form given by equations (32), (33), (35) and (36); where in absolute values: $b_i' + b_i'' = b_i$, $c_i' + c_i'' = c_i$, $d_i' + d_i'' = d_i$, $h_i' + h_i'' = h_i$, $i_i' + i_i'' = i_i$, $j_i' + j_i'' = j_i$ and $k_i' + k_i'' = k_i$, for $i = y, p$. We can check the results by making the respective weigthed sums.

A.II Alternative loss functions

Solving the optimization problem for a loss function like $L_i = y_i^2 + \sigma_i g_i^2$, (see Appendix A.III), the absolute value of the coefficient for an expansionary real shock (being similar for the rest) in the reaction function of the first country, would be:

$$\left|\frac{d_y''}{i_y'}\right|$$

On the other hand, if the loss function is $L_i = y_i^2 + \sigma_i g_i^2 + \pi_i p_i^2$, we would obtain:

$$\left|\frac{i_y' d_y' + i_p' d_p' \pi_1}{\left(i_y'\right)^2 + \left(i_p'\right)^2 \pi_1}\right|$$

And the relationship between these absolute values would be:

$$\left|d_p' i_y'\right| \lesseqgtr \left|i_p' d_y'\right|$$

In this way, we can conclude that the size of the coefficients depend on the effects of the shock on the economy (d_y', d_p') and on the use of the institutional variable as an instrument (i_y', i_p'). In conclusion, the desirability of including changes in prices as objective, will depend on the kind of shock that occurs.. On the other hand, since both the competitive and cooperative solutions will depend on the reaction function coefficients, the relative size of the solution will depend on the size of the reaction functions coefficients.

A.III The coefficients of the reaction functions

In absolute value, the coefficients are equal in both the "*locomotive effect*" and "*beggar-thy-neighbour effect" cases.*

We have, for the reaction function of country 1:

$$R_1 = \frac{i_y''}{i_y'}, \quad R_2 = \frac{c_y'}{i_y'}, \quad R_3 = \frac{c_y''}{i_y'},$$

$$R_4 = \frac{d_y'}{i_y'}, \quad R_5 = \frac{d_y''}{i_y'}, \quad R_{1,6} = \frac{h_y'}{i_y'},$$

$$R_7 = \frac{a_y}{i_y'}, \quad R_{1,8} = \frac{b_y'}{i_y'}, \quad R_{1,9} = \frac{j_y'}{i_y'}$$

The coefficients that differ for country 2 are:

$$R_{2,6} = \frac{h_y''}{i_y'}, \quad R_{2,8} = \frac{b_y''}{i_y'}, \quad R_{2,9} = \frac{j_y''}{i_y'},$$

A.IV The Nash-Cournot solution

THE LOCOMOTIVE EFFECT

For country 1:

$$N_{1,1} = D(i_y''c_y'' - i_y'c_y') \quad N_{1,2} = D(i_y''c_y' - i_y'c_y'')$$

$$N_{1,3} = D(i_y''d_y'' - i_y'd_y') \quad N_{1,4} = D(i_y''d_y' - i_y'd_y'')$$

$$N_{1,5} = D(i_y''h_y'' - i_y'h_y') \quad N_{1,6} = Da_y(i_y'' - i_y')$$

$$N_{1,7} = D(i_y''b_y'' - i_y'b_y') \quad N_{1,8} = D(i_y'j_y' - i_y''j_y'')$$

where $D = \frac{1}{(i_y')^2 - (i_y'')^2}$
and for country 2:

$$N_{2,1} = N_{1,2} \quad N_{2,2} = N_{1,1}$$

$$N_{2,3} = N_{1,4} \quad N_{2,4} = N_{1,3}$$

$$N_{2,5} = D(i_y''h_y' - i_y'h_y'') \quad N_{2,6} = N_{1,6}$$

$$N_{2,7} = D(i_y''b_y' - i_y'b_y'') \quad N_{2,8} = D(i_y'j_y'' - i_y''j_y')$$

where $D = \frac{1}{(i_y')^2 - (i_y'')^2}$

THE BEGGAR-THY-NEIGHBOUR EFFECT

For country 1:

$$N'_{1,1} = D(-i''_y c''_y - i'_y c'_y) \quad N'_{1,2} = D(i''_y c'_y + i'_y c''_y)$$

$$N'_{1,3} = D(-i''_y d''_y - i'_y d'_y) \quad N'_{1,4} = D(i''_y d'_y + i'_y d''_y)$$

$$N'_{1,5} = D(-i''_y h''_y + i'_y h'_y) \quad N'_{1,6} = Da_y(i''_y - i'_y)$$

$$N'_{1,7} = D(-i''_y b''_y + i'_y b'_y) \quad N'_{1,8} = D(i'_y j'_y - i''_y j''_y)$$

where $D = \frac{1}{(i'_y)^2 - (i''_y)^2}$
and for country 2:

$$N'_{2,1} = N'_{1,2} \quad N'_{2,2} = N'_{1,1}$$

$$N'_{2,3} = N'_{1,4} \quad N'_{2,4} = N'_{1,3}$$

$$N'_{2,5} = D(-i''_y h'_y + i'_y h''_y) \quad N'_{2,6} = N'_{1,6}$$

$$N'_{2,7} = D(-i''_y b'_y + i'_y b''_y) \quad N'_{2,8} = D(i'_y j''_y - i''_y j'_y)$$

where $D = \frac{1}{(i'_y)^2 - (i''_y)^2}$

A.V The Nash-Stackelberg solution

THE LOCOMOTIVE EFFECT
The coefficients are:

$$
\begin{aligned}
S_{1,1} &= N_{1,1} & S_{2,1} &= D\left[-c''_y + i''_y S_{1,1}\right] \\
S_{1,2} &= N_{1,2} & S_{2,2} &= D\left[-c'_y + i''_y S_{1,2}\right] \\
S_{1,3} &= N_{1,3} & S_{2,3} &= D\left[-d''_y - i''_y S_{1,3}\right] \\
S_{1,4} &= N_{1,4} & S_{2,4} &= D\left[-d'_y + i''_y S_{1,4}\right] \\
S_{1,5} &= N_{1,5} & S_{2,5} &= D\left[-h''_y + i''_y S_{1,5}\right] \\
S_{1,6} &= N_{1,6} & S_{2,6} &= D\left[-a_y + i''_y S_{1,6}\right] \\
S_{1,7} &= N_{1,7} & S_{2,7} &= D\left[-b''_y + i''_y S_{1,7}\right] \\
S_{1,8} &= N_{1,8} & S_{2,8} &= D\left[j''_y - i''_y S_{1,8}\right]
\end{aligned}
$$

where $D = \frac{1}{i'_y}$.

THE BEGGAR-THY-NEIGHBOUR EFFECT

The coefficients are:

$$
\begin{aligned}
S'_{1,1} &= N'_{1,1} & S'_{2,1} &= S_{2,1} \\
S'_{1,2} &= N'_{1,2} & S'_{2,2} &= D\left[-c'_y - i''_y S_{1,2}\right] \\
S'_{1,3} &= N'_{1,3} & S'_{2,3} &= S_{2,3} \\
S'_{1,4} &= N'_{1,4} & S'_{2,4} &= D\left[-d'_y - i''_y S_{1,4}\right] \\
S'_{1,5} &= N'_{1,5} & S'_{2,5} &= D\left[-h''_y - i''_y S_{1,5}\right] \\
S'_{1,6} &= N'_{1,6} & S'_{2,6} &= S_{2,6} \\
S'_{1,7} &= N'_{1,7} & S'_{2,7} &= D\left[-b''_y - i''_y S_{1,7}\right] \\
S'_{1,8} &= N'_{1,8} & S'_{2,8} &= S_{2,8}
\end{aligned}
$$

where $D = \frac{1}{i'_y}$.

A.VI The cooperative solution

THE LOCOMOTIVE EFFECT

For country 1:

$$
\begin{aligned}
C_{1,1} &= D\left[(c'_y i'_y + c''_y i''_y) - (c''_y i'_y + c'_y i''_y)A\right] \\
C_{1,2} &= D\left[(c''_y i'_y + c'_y i''_y) - (c'_y i'_y + c''_y i''_y)A\right] \\
C_{1,3} &= D\left[(d'_y i'_y + d''_y i''_y) - (d''_y i'_y + d'_y i''_y)A\right] \\
C_{1,4} &= D\left[(d''_y i'_y + d'_y i''_y) - (d'_y i'_y + d''_y i''_y)A\right] \\
C_{1,5} &= D\left[(h'_y i'_y + h''_y i''_y) - (h''_y i'_y + h'_y i''_y)A\right] \\
C_{1,6} &= D\left[a_y(i'_y + i''_y)(1 - A)\right] \\
C_{1,7} &= D\left[(b'_y i'_y + b''_y i''_y) - (b''_y i'_y + b'_y i''_y)A\right] \\
C_{1,8} &= D\left[(i'_y)^2 + (i''_y)^2 + 4(i'_y)^2(i''_y)^2\right] \\
C_{1,9} &= D\left[((i'_y)^2 + (i''_y)^2)2i'_y i''_y + 2i'_y i''_y\right] \\
C_{1,10} &= D\left[(j'_y i'_y + j''_y i''_y) + (i''_y j'_y + i'_y j''_y)A\right]
\end{aligned}
$$

and for country 2:

$$
\begin{aligned}
C_{2,1} &= C_{1,2} \\
C_{2,2} &= C_{1,1} \\
C_{2,3} &= C_{1,4} \\
C_{2,4} &= C_{1,3} \\
C_{2,5} &= D\left[(h''_y i'_y + h'_y i''_y) - (h'_y i'_y + h''_y i''_y)A\right] \\
C_{2,6} &= C_{1,6} \\
C_{2,7} &= D\left[(b''_y i'_y + b'_y i''_y) - (b'_y i'_y + b''_y i''_y)A\right] \\
C_{2,8} &= C_{1,9} \\
C_{2,9} &= C_{1,8} \\
C_{2,10} &= D\left[(i''_y j'_y + i'_y j''_y) + (j'_y i'_y + j''_y i''_y)A\right]
\end{aligned}
$$

where $D = \frac{1}{2i'_y i''_y - 1}$ and $A = 2i'_y i''_y$.

THE BEGGAR-THY-NEIGHBOUR EFFECT

For country 1:

$$
\begin{aligned}
C'_{1,1} &= D\left[(c'_y i'_y - c''_y i''_y) - (c''_y i'_y + c'_y i''_y)A\right] \\
C'_{1,2} &= D\left[-(c''_y i'_y - c'_y i''_y) - (c'_y i'_y + c''_y i''_y)A\right] \\
C'_{1,3} &= D\left[(d'_y i'_y - d''_y i''_y) - (d''_y i'_y + d'_y i''_y)A\right] \\
C'_{1,4} &= D\left[-(d''_y i'_y - d'_y i''_y) - (d'_y i'_y + d''_y i''_y)A\right] \\
C'_{1,5} &= D\left[(h'_y i'_y - h''_y i''_y) - (h''_y i'_y - h'_y i''_y)A\right] \\
C'_{1,6} &= D\left[a_y(i'_y + i''_y)(1 - A)\right] \\
C'_{1,7} &= D\left[(b'_y i'_y - b''_y i''_y) - (b''_y i'_y - b'_y i''_y)A\right] \\
C'_{1,8} &= D\left[(i'_y)^2 + (i''_y)^2 + 4(i'_y)^2(i''_y)^2\right] \\
C'_{1,9} &= D\left[((i'_y)^2 + (i''_y)^2)2i'_y i''_y + 2i'_y i''_y\right] \\
C'_{1,10} &= D\left[(j'_y i'_y + j''_y i''_y) + (i''_y j'_y + i'_y j''_y)A\right]
\end{aligned}
$$

and for country 2:

$$
\begin{aligned}
C'_{2,1} &= C'_{1,2}\\
C'_{2,2} &= C'_{1,1}\\
C'_{2,3} &= C'_{1,4}\\
C'_{2,4} &= C'_{1,3}\\
C'_{2,5} &= D\left[(h''_y i'_y - h'_y i''_y) - (h'_y i'_y - h''_y i''_y)A\right]\\
C'_{2,6} &= C'_{1,6}\\
C'_{2,7} &= D\left[(b''_y i'_y - b'_y i''_y) - (b'_y i'_y - b''_y i''_y)A\right]\\
C'_{2,8} &= C'_{1,9}\\
C'_{2,9} &= C'_{1,8}\\
C'_{2,10} &= D\left[(i''_y j'_y + i'_y j''_y) + (j'_y i'_y + j''_y i''_y)A\right]
\end{aligned}
$$

where $D = \frac{1}{2i'_y i''_y - 1}$ and $A = 2i'_y i''_y$.

A.VII Externalities

THE LOCOMOTIVE EFFECT

$$\frac{\partial L_1}{\partial t_2} = 2i''_y(a_y m + b'_y m^* + c'_y g_1 + c''_y g_2 + d'_y f_1 + d''_y f_2$$

$$+h'_y f^* - i'_y s_1 - i''_y s_2 - j'_y s^* + i'_y t_1 + i''_y t_2) \neq 0$$

$$\frac{\partial L_2}{\partial t_1} = 2i''_y(a_y m + b''_y m^* + c'_y g_2 + c''_y g_1 + d'_y f_2 + d''_y f_1$$

$$+h''_y f^* - i'_y s_2 - i''_y s_1 - j''_y s^* + i'_y t_2 + i''_y t_1) \neq 0$$

THE BEGGAR-THY-NEIGHBOUR EFFECT

$$\frac{\partial L_1}{\partial t_2} = 2i''_y(a_y m - b'_y m^* + c'_y g_1 - c''_y g_2 + d'_y f_1 - d''_y f_2$$

$$-h_y^{'}f^* - i_y^{'}s_1 - i_y^{''}s_2 - j_y^{'}s^* + i_y^{'}t_1 + i_y^{''}t_2) \neq 0$$

$$\frac{\partial L_2}{\partial t_1} = 2i_y^{''}(a_y m - b_y^{''}m^* + c_y^{'}g_2 - c_y^{''}g_1 + d_y^{'}f_2 - d_y^{''}f_1$$

$$-h_y^{''}f^* - i_y^{'}s_2 - i_y^{''}s_1 - j_y^{''}s^* + i_y^{'}t_2 + i_y^{''}t_1) \neq 0$$

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