The policy mix in a monetary union: who bears the burden of asymmetric shocks' stabilisation?

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The policy mix in a monetary union: Who bears the burden of asymmetric shocks' stabilisation?

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Abstract

We utilise a standard reduced-form neo-Keynesian model in a monetary union, in which the monetary authority and the fiscal authorities strategically interact, to explore who, under alternative institutional arrangements (strategic and fiscal regimes) and shocks' configurations, bears the burden of asymmetric shocks' stabilisation. We show that in the core/periphery fiscal regime, described by an asymmetry in the sequence of moves between the core and the peripheral member-states, asymmetric shocks pass through at the union level to the inflation rate and the output gap when there are strategically significant spill-over effects and the monetary policy's and fiscal policies' instruments are not perfect substitutes in the stabilisation process. The monetary authority reacts to asymmetric shocks, but does not succeed in fully offsetting them. The first best implies the coordination of fiscal policies. A second best embraces the fiscal leadership strategic regime (as a form of implicit coordination), when there are strong interconnections in the union, or the use of policy instruments by the fiscal authorities that directly decrease inflation when fiscal policy is expansionary, such as taxes, production subsidies or public investment, when there is a strong cost channel of monetary policy.

KEYWORDS

asymmetric shocks, core/periphery set-up, monetary union, policy mix, strategic interactions

1 | INTRODUCTION

This paper focuses on the stabilisation of asymmetric shocks in a monetary union, in general, but with a clear reference to the Economic and Monetary Union (EMU) in Europe, in particular. We utilise a standard reduced-form neo-Keynesian model in a monetary union, based on an aggregate demand (AD) equation and a Philips curve (PC) relation, when the monetary and the fiscal authorities strategically interact under strategically significant spill-over effects, to explore who bears the burden of shocks' stabilisation under alternative shocks' configurations and institutional arrangements, meaning strategic and fiscal regimes. To do that, we extend the model by Chortareas and Mavrodimitrakis (2021) to a multi-country setting under country-size asymmetry, considering also fiscal sequential asymmetries (see, e.g., Kirsanova et al. (2018); Hughes Hallett and Mavrodimitrakis (2019)) and a broader palette of shocks (see, e.g., Andersen (2008)).

The traditional theory of optimum currency areas, following Mundell (1961), implies that in the absence of wage flexibility and labour mobility, countries facing

asymmetric shocks would be worse off in a monetary union. The empirical evidence supports the importance of asymmetric shocks as the main source of heterogeneity in the EMU (Jondeau & Sahuc, 2008); and strong asymmetries in shocks between the core and the periphery have been detected (Pentecote & Huchet-Bourdon, 2012). Campos and Macchiarelli (2016) investigate the core-periphery pattern in the EMU and, although they find that this has been weakened over time, a new, smaller periphery included by the PIGS, with dynamics systematically different from the rest of the union, can be detected. De Grauwe and Ji (2016) find that although the business cycles are highly correlated, their amplitudes vary significantly, with some countries (Greece, Ireland, Spain) experiencing strong booms and busts and other countries (Germany, Belgium, Austria) much milder cyclical movements. The existence of asymmetric shocks enhances the potential role of national fiscal policies, whose (strategic) interactions among them and with monetary policy become crucial for the macroeconomic outcomes at both the union and country levels.

The paper is based on a substantial literature on strategic fiscal/monetary policy interactions in monetary unions that focuses on stabilisation policies after shocks, pioneered by Dixit and Lambertini (2003a) and Dixit and Lambertini (2003b); and formalised further by Kempf and von Thadden (2013). Thereafter, the literature has focused on various issues that alter the nature of the policy games, affecting the policy-mix outcomes and coordination problems in a monetary union. In particular, Chortareas and Mavrodimitrakis (2021) have shown how the policy-mix outcomes and coordination problems depend on relative policy effectiveness and the leadership regimes, when the two policy instruments, namely the fiscal stance and the common nominal interest rate, are not perfect substitutes in the stabilisation process; which is the case when the policy instruments are allowed to have short-run supply-side effects, along with their usual demand-side ones.[1]

The literature mainly considers two fiscal regimes, namely the narrow (noncooperative Nash) and broad (cooperative Nash) coordination ones, following Von Hagen and Mundschenk (2003). The main result reads that, at equilibrium, the union-wide macroeconomic variables are only affected by union-wide shocks, and not by shocks' asymmetries. Monetary policy does not react to shocks' asymmetries, but only to union-wide shocks, hence the stabilisation burden (of asymmetric shocks) lies entirely on the national fiscal authorities; where its distribution is being determined by their strategic interactions, and country-specific output gaps differ. Exploring also an alternative fiscal regime that assumes a core/periphery set-up in which there are asymmetries in the sequence of moves between the core and the peripheral fiscal authorities in the union, we show that the previous result does not hold under imperfect instrument substitutability and strategically significant spill-over effects. To be precise, assuming (i) strategically significant spill-over effects; (ii) fiscal sequential asymmetries; and (iii) imperfect instrument substitutability, results in shocks' asymmetries between the core and the periphery passing through at the union level, affecting both the equilibrium inflation rate and output gap. Monetary policy now reacts to asymmetric shocks, but cannot succeed in fully offsetting them. Moreover, relative output gaps betwen the core and the rest of the union are also affected by union-wide shocks, and not only by shocks' asymmetries; hence common (perfectly asymmetric) shocks deliver differing output gaps between the core and the rest of the union. The notion of strategically significant spill-over effects follows Kempf and von Thadden (2013) and is further defined here for the purpose of our analysis,[2] fiscal sequential asymmetries have been recently explored by Hughes Hallett and Mavrodimitrakis (2019), but under perfect instrument substitutability, where this particular assumption and its relevance are explicitly discussed,[3] while imperfect instrument substitutability and the resulting relative policy effectiveness follows Chortareas and Mavrodimitrakis (2021).

We can summarise our results as follows: (i) country-size asymmetry and the fiscal regimes matter (in that they provide differing macroeconomic outcomes), excluding the broad coordination fiscal regime (where country-size asymmetry does not matter), as long as there are strategically significant spill-over effects; (ii) in both the broad coordination fiscal regime and the narrow coordination one under country-size symmetry, all the macroeconomic variables at the union level are affected by union-wide shocks and not by shocks' asymmetries; hence idiosyncratic (perfectly asymmetric) shocks do not matter at the union level, and the national fiscal authorities react to asymmetric shocks in the exact opposite way, so the union-wide fiscal stance remains neutral and monetary policy passive; (iii) under fiscal sequential asymmetries (in the core/periphery set-up), asymmetric shocks between the core and the peripheral member-states pass through at the union level if the two policy instruments are not perfect substitutes in the stabilisation process. The rationale is the following: asymmetric shocks induce asymmetric fiscal reactions, since there are strategically significant spill-over effects, resulting in the union-wide fiscal stance to become non-neutral; then, the monetary authority explicitly reacts (becomes active) to those asymmetric fiscal reactions, hence to the asymmetric shocks; but it cannot match the latter's impact on union-wide inflation and output gap, unless the policy instruments are perfect substitutes in the stabilisation process. Moreover, relative output gaps are affected by union-wide shocks, and not only by asymmetric ones; hence common shocks deliver different output gaps between the core member-state and the rest of the union.

The structure of the paper is as follows: Section 2 presents the model and relates it to the rest of the literature; Section 3 explores the monetary authority's and the national fiscal authorities' optimisation programmes and the corresponding (union-wide and country-specific) policy rules for all the alternative institutional arrangements (strategic and fiscal regimes), while Section 4 proceeds to the corresponding union-wide and relative equilibrium solutions; finally, Section 5 concludes the paper.

2 | THE MODEL

The model is based on Chortareas and Mavrodimitrakis (2021), extended to a multi-country setting under country-size asymmetry, including a richer shocks' palette. Country j economy's descriptive equations are given by:

$$y_j = -\delta_r\left(i - \pi_j^e - \overline{r}_j\right) - \delta_\tau\left(\pi_j - \pi\right) + \delta_y y + \delta_g g_j + \delta_u u_j \quad (1)$$

$$\pi_j = \pi_j^e + \omega_y y_j + \omega_g g_j + \omega_i i + \omega_u u_j \quad (2)$$

where Equation (1) describes aggregate demand and Equation (2) represents a PC relation. All variables represent log-deviations from long-run equilibrium values, apart from the decimal common nominal interest rate, i, which is the monetary policy's instrument. The absence of the j subscript denotes union-wide variables, given by $x = \sum_{j=1}^{n} q_j x_j$ for every variable x, where n is the number of countries in the union and q_j is the weight of country j in the union, in that $\sum_{j=1}^{n} q_j = 1$. Inflation is represented by π, y represents the output gap, and g is the fiscal policy's instrument, which captures the overall fiscal stance. The variable $\overline{r}_j$ represents the long-run equilibrium real interest rate, which for simplicity is set equal to zero for all countries, while π_j^e denotes the private sector's (rational) expectation on country j's future inflation. Finally, u_j is an independently and identically distributed (i.i.d.; random) shock, with zero mean and known constant variance. Since we care about policy responses to shocks, macroeconomic adjustments are assumed to take place instantly and shocks are white noise (Saraceno & Tamborini, 2020).

All the parameters in the AD Equation (1) are positive, apart from δ_u. The parameter δ_r captures the interest sensitivity of aggregate demand, while δ_g captures the demand effect of fiscal policy. The parameters δ_τ and δ_y capture the interconnections among the member-states in the union, representing direct spill-over effects; that is, the effect of competitiveness on domestic output (a terms-of-trade effect) and the relative openness of the economy (a trade effect), respectively. Higher domestic activity leads to higher prices and thus makes it possible for foreign partners to increase their market share, while a domestic fiscal expansion benefits trading partners by an increase in demand for foreign products.

Following the Calvo (1983) model of staggered price adjustment, where a fraction of firms are assumed to adjust prices each period, the PC is a relation between inflation, expected inflation, and firms' real marginal costs; where the latter's impact on inflation mainly depends on the degree of price stickiness (the fraction of firms that do not adjust their prices each period). Looking at our PC relation, Equation (2), its slope is given by the positive parameter, ω_y, while both policy instruments, namely the country-specific fiscal stance and the common nominal interest rate, can directly affect the country-specific inflation rate; meaning that they both directly affect real marginal costs. The direct effect of fiscal policy on inflation, ω_g, can be either positive or negative, capturing short-run supply-side effects of alternative fiscal policy's instruments, since, following Andersen (2005), fiscal policy may also have (temporarily) separate effects on wage (price) inflation. For example, public expansions financed by value-added and excise taxes add (temporarily) to the inflationary pressure in the economy. A negative effect can emerge, however, via public investment or a production subsidy that raises private productivity, increasing the supply of goods (see Debrun, 2000; Dixit & Lambertini, 2003a). Another channel can exist through deep-habit formation, when private agents form habits from the consumption of individual goods (Ravn et al., 2006). In an economy with imperfectly competitive product markets, deep-habit formation creates a time-varying mark-up, which negatively depends on government spending through price-elasticity and intertemporal effects.[4] We follow Andersen (2008) assuming that the overall impact of country-specific fiscal policy on both country-specific inflation and the output gap is positive; that is, $\frac{\partial \pi_j}{\partial g_j} = \omega_g + \omega_y \delta_g > 0$ and $\frac{\partial y_j}{\partial g_j} = \delta_g - \delta_\tau \omega_g > 0$. These assumptions make the fiscal stance a demand-side policy instrument.

The direct effect of the interest rate on inflation follows the cost channel of monetary policy, as this is demonstrated by Ravenna and Walsh (2006). The typical New-Keynesian model does not explicitly incorporate investment and its response to the interest rate. The working capital channel (e.g., Christiano (1991); Christiano and Eichenbaum (1992)), however, assumes that the labour input must be financed by loans, implying that monetary policy affects the economy by changing variable production costs. In Ravenna and Walsh (2006),

monopolistically competitive firms must borrow from a financial intermediary to pay for wages in advance. Thus, prices set by firms directly depend on the cost of borrowing (the loan rate); in particular, under a high (low) loan rate, prices will be also high (low); hence ω_i is positive and defines the cost-channel effect (see, also, Kobayashi (2008)).[5] For simplicity, we assume that country-specific loan rates are equal, implying fully integrated financial markets, and equal to the common nominal interest rate that the monetary authority sets at the union level, implying perfect competition in financial markets.[6] The cost channel creates a meaningful policy trade-off for the central bank without the need for an exogenous cost-push shock. Thus, both inflation and the output gap fluctuate in response to supply/demand disturbances under the optimal policy.

Turning now to the shock's direct effects on the output gap and inflation, δ_u and ω_u, respectively, they can be of either sign, capturing alternative specifications; e.g., a demand shock assumes $\delta_u > 0$ and $\omega_u > 0$, while a supply shock $\delta_u > 0$ and $\omega_u < 0$. Then, a pure cost-push shock assumes $\delta_u = 0$ and $\omega_u > 0$, while the opposite would assume a pure demand shock (Andersen, 2008). The Covid-19 pandemic can be captured by $\delta_u < 0$ (lockdown) and $\omega_u > 0$ (shutdown). Lockdowns, as an (initial) policy response to reduce social interaction, hence the spread of the virus, have a negative impact on AD, while shutdowns create disruptions to the supply-side of the economy. However, inflation decreased dramatically during the initial months of the Covid-19 pandemic, which, following also the analysis of Shapiro (2020), reveals that the negative demand shock far prevailed the negative supply shock; so, any possible upward price pressure stemming from supply-side constraints. In our case, this implies $\frac{\partial \pi_i}{\partial u_j} = \delta_u \omega_y + \omega_u < 0$. Last but not least, a financial shock, defined as a premium to country-specific interest rates, can be captured by $\delta_u = -\delta_r < 0$ and $\omega_u = \omega_i > 0$.[7]

We can compute the descriptive equations at the union level by averaging the country-specific Equations (1) and (2) to obtain:

$$y = \frac{1}{1-\delta_y}\left[-\delta_r(i-\pi^e) + \delta_g g + \delta_u u\right] \tag{3}$$

$$\pi = \pi^e + \omega_y y + \omega_g g + \omega_i i + \omega_u u \tag{4}$$

where the trade effect, δ_y, works as a multiplier, since increases in either domestic or foreign AD initiate consequent increases in domestic AD, where their overall impact at the union level is captured by $\frac{1}{1-\delta_y} > 0$; hence must be $\delta_y \in (0,1)$.

The authorities' loss functions are quite standard in this literature (see, e.g., Uhlig (2002) and Andersen (2008)) and are given by:

$$L_M = \frac{1}{2}\left(\pi^2 + \alpha_M y^2\right) \tag{5}$$

$$L_{F_j} = \frac{1}{2}\left(g_j^2 + \alpha_F y_j^2\right) \tag{6}$$

where 'M' stands for the 'Monetary' authority and 'F' for the national 'Fiscal' authorities. The parameter $\alpha_F > 0$ is the weight that the national fiscal authorities place on output-gap stabilisation relative to inflation stabilisation, while the parameter $\alpha_M > 0$ defines the weight the central bank puts on (union-wide) output-gap stabilisation relative to inflation stabilisation. The common central bank in the union cares about union-wide data and operates under a flexible inflation-targeting monetary policy framework. Considering the national fiscal authorities, the inclusion of country-specific fiscal stances in their loss functions reflects the desire of governments to both stabilise their economies and run a fiscally balanced budget (Uhlig, 2002).[8] In this sense, the parameter α_F can be thought of as the weight the fiscal authority puts on a stable economy relative to a balanced budget; the lower this weight, the less the fiscal policy's flexibility to stabilise (country-specific) shocks. An $\alpha_F = 0$ assumes a passive country-specific fiscal policy, while the symmetry assumption on positive/negative fiscal stance in the loss function penalises volatility in national deficits; hence assuming a costly policy instrument. This specification further assumes an unpleasant debt arithmetic in the case of a permanently positive fiscal stance; that is, a structural deficit (Bofinger & Mayer, 2007). Since the fiscal stance is the fiscal authorities' policy instrument, it simultaneously defines a target and an instrument. Moreover, the national fiscal authorities are not concerned about country-specific inflation stabilisation, since they have delegated this task to the monetary authority in the union (Muscatelli et al., 2012). Including a terms-of-trade effect in the AD equation, however, creates an implicit preference for (country-specific) inflation stabilisation for the national fiscal authorities (Andersen, 2005).[9]

The time context begins with the private sector forming expectations about future inflation rationally; then, the shocks are realised; finally, the authorities choose their control instrument in order to achieve their goals according to the particular institutional arrangement (strategic regime), hence acting in discretion. The strategic regime of simultaneous moves demands all the authorities to act independently and simultaneously, while in the two leadership regimes, namely fiscal and

TABLE 1 The authorities' stages of moves under the alternative institutional arrangements.

Regimes		Stages of moves		
Strategic	**Fiscal**	**First**	**Second**	**Third**
Simultaneous move	NC	All; FAs non-cooperative Nash	N/A	N/A
	BC	All; FAs cooperative Nash	N/A	N/A
Fiscal leadership	NC	FAs lead; non-cooperative Nash	MA follows	N/A
	BC	FAs lead; cooperative Nash	MA follows	N/A
	C/P	Core FA leads	Peripheral FAs follow; non-cooperative Nash	MA follows
Monetary leadership	NC	MA leads	FAs follow; non-cooperative Nash	N/A
	BC	MA leads	FAs follow; cooperative Nash	N/A
	C/P	MA leads	Core FA follows	Peripheral FAs follow; non-cooperative Nash

monetary leadership, the authority having the lead makes its move prior to the follower authority, while it considers the way the latter will react to its choice of the policy instrument. In the fiscal leadership strategic regime, the national fiscal authorities lead the game and the central bank follows, while in the monetary leadership strategic regime the monetary authority leads and the national fiscal authorities follow. No time-inconsistency issues are involved, and $\pi_j^e = \pi^e = 0$ (see, e.g., Andersen, 2008; Uhlig, 2002; among others).

The national fiscal authorities can operate under three alternative fiscal regimes: (i) a regime of narrow coordination, which corresponds to a simultaneous-move game among them; (ii) a regime of broad (horizontal) coordination, where they minimise a joint loss function (given below); and (iii) a core/periphery set-up, described by fiscal sequential asymmetries, in which a core fiscal authority is the leader against the rest of the fiscal authorities that move simultaneously (as the followers), constituting the periphery of the union. The loss function under horizontal coordination is given by:

$$L_F = \sum_{j=1}^{n} q_j L_{F_j} \tag{7}$$

Table 1 helps clarifying the institutional arrangements under consideration.[10] The *Stages of Moves* corresponds to the exact stage that each authority moves after the shocks' realisation. *NC* stands for the narrow coordination fiscal regime, *BC* for the broad coordination and *C/P* for the core/periphery set-up; while *FAs* for the fiscal authorities and *MA* for the monetary authority. For example, in the simultaneous-move strategic regime, all the authorities play in the First Stage, and the fiscal authorities can cooperate or not, while in the core/periphery fiscal regime under fiscal leadership, the core fiscal authority moves in the First Stage, then in the Second Stage the peripheral fiscal authorities move simultaneously and independently (hence the non-cooperative Nash), and finally in the Third Stage the monetary authority completes the game. Naturally, the Third Stage only exists in the core/periphery set-up. Neither alternative regimes with the monetary authority playing between some or cooperate with any of the national fiscal authorities,[11] nor any cooperation among the peripheral member-states' fiscal authorities in the core/periphery set-up are allowed.

The reduced-form country-specific AD equation can be computed as:

$$y_j = -Z_i i + Z_{g_j} g_j + Z_g g - Z_{du}\omega_u\left(u_j - u\right) + \delta_u\left(Z_{u_j} u_j + Z_u u\right) \tag{8}$$

where the (semi-)elasticities are given by: $Z_i = \frac{\delta_r}{1-\delta_y}$; $Z_{g_j} = \frac{\delta_g - \delta_\tau \omega_g}{1+\delta_\tau \omega_y}$; $Z_g = \frac{1}{1+\delta_\tau\omega_y}\left[\frac{\delta_g\left(\delta_y+\delta_\tau\omega_y\right)}{1-\delta_y} + \delta_\tau\omega_g\right]$; $Z_{du} = \frac{\delta_\tau}{1+\delta_\tau\omega_y}$; $Z_{u_j} = \frac{1}{1+\delta_\tau\omega_y}$; $Z_u = \frac{1}{1-\delta_y}\frac{\delta_y+\delta_\tau\omega_y}{1+\delta_\tau\omega_y}$; and they are all positive under our parameters' restrictions.[12] Equation (8) defines a target variable, namely country-specific output demand, with respect to the control variables (the monetary policy's instrument and the country-specific and union-wide fiscal stances) and the exogenous shocks, being domestic or union-wide.[13] Looking at the union-wide AD Equation (3), we can express the impacts of the nominal interest rate, the union-wide fiscal stance, and the union-wide shock using these elasticities. Specifically: $\frac{\partial y}{\partial g} = Z_{g_j} + Z_g = \frac{\delta_g}{1-\delta_y}$; $\frac{\partial y}{\partial i} = -Z_i$; and $\frac{\partial y}{\partial u} = \delta_u\left(Z_{u_j} + Z_u\right) = \frac{\delta_u}{1-\delta_y}$.

The before-mentioned elasticities reveal the importance of the interconnections in the union. First, domestic output demand is directly affected by the union-wide shock and the fiscal stance, but also by asymmetries in shocks that have supply-side effects (i.e., shocks that are not pure demand shocks), only through the interconnections. In the opposite case of $\delta_y = \delta_\tau = 0$, domestic aggregate demand is only affected by domestic shocks that have demand-side effects; since $Z_g = Z_{du} = Z_u = 0$. This paper focuses on asymmetric shocks, defined as $u_j - u$. We can easily see that, before policies' responses, asymmetric shocks affect aggregate demand if (i) shocks have supply-side effects ($\omega_u \neq 0$), and (ii) there is a terms-of-trade effect ($\delta_\tau \neq 0$, so $Z_{du} \neq 0$). Considering, for example, Germany and the rest of the union, if both face a positive cost-push shock, inflation in Germany increases, hence leading to a reduction in domestic aggregate demand, but at the same time inflation in the rest of the union increases, which increases Germany's aggreagate demand. So, the terms of trade might worsen or improve, depending on the size of the shocks. If the shock in Germany is greater than the union average, then Germany's terms of trade worsen; so, a reduction in domestic aggregate demand. Germany losses in competitiveness vis-a-vis the rest of the union. Second, the terms-of-trade effect reduces the impact of domestic fiscal policy on domestic aggregate demand, since an expansionary fiscal policy increases inflation hence worsening the terms of trade. Output demand is further decreased if fiscal policy can directly affect inflation positively, too, while in the opposite case of a negative direct effect, the total effect is ambiguous. Third, none of the above elasticities depend on the cost channel of monetary policy, since the latter is assumed to be symmetric in the monetary union. This means that the cost channel does not affect the terms of trade and aggregate demand. However, asymmetries in financial shocks ($\omega_u = \omega_i$) negatively affect domestic aggregate demand when there is a cost-channel effect ($\omega_i \neq 0$).

The post-pandemic environment, characterised by surging energy prices, assumes an adverse ($u_j < 0$) and deeply asymmetric ($u_j \neq u$) supply shock ($\omega_u < 0$). The national fiscal authorities would react to both country-specific and asymmetric shocks, following their loss function, Equation (6); but the monetary authority is not concerned about those shocks, following its loss function, Equation (5), and the union-wide descriptive Equations (3) and (4); hence it will not react unless those shocks pass through to the union-wide fiscal stance, since the latter affects the union-wide output gap, hence inflation. And there is also the direct effect of fiscal policy on inflation ($\omega_g \neq 0$). We show how the union-wide fiscal stance is affected by asymmetric shocks, and why the monetary authority might not be able to fully offset those shocks.

By combining the union-wide with the country-specific AD Equations (3) and (8), respectively, we can get the relative output gap, as:

$$y_j - y = Z_{g_j}\left(g_j - g\right) + \left(Z_{u_j}\delta_u - Z_{du}\omega_u\right)\left(u_j - u\right) \quad (9)$$

Equation (9) states that the country-specific output gap differs from the average one at the union if: (i) domestic fiscal stance differs from union-wide one; and (ii) there are shocks' asymmetries. Regarding the latter, asymmetric shocks matter for relative output gaps, as long as country-specific shocks matter for country-specific output gaps in the first place; namely, $\frac{\partial y_j}{\partial u_j} = Z_{u_j}\delta_u - Z_{du}\omega_u \neq 0$ following the country-specific AD Equation (8). The opposite case requires demand shocks with supply-side effects, since δ_u and ω_u should be of the same sign, and the supply-side effect of the (e.g., positive) shock which reduces aggregate demand through the terms-of-trade effect to exactly offset the impact of the positive demand shock on aggregate demand. In general, country-size asymmetry, monetary policy, and the strategic regimes should all matter for relative output gaps as long as they affect relative fiscal stances.

3 | THE AUTHORITIES' OPTIMISATION PROGRAMMES: POLICY RULES

The monetary authority controls the common nominal interest rate, i, and minimises its loss function, Equation (5), subject to the union-wide descriptive Equations (3) and (4). Each national fiscal authority controls its fiscal stance, g_j; under narrow coordination, the fiscal authorities minimise their own loss functions, described by Equation (6), while under broad coordination they minimise their joint loss function, Equation (7); both subject to the country-specific AD Equation (8). In the core/periphery set-up, the lead (core) fiscal authority takes also into account the peripheral authorities' minimisation programmes. In all the alternative institutional arrangements, each authority's optimisation programme delivers a policy rule that relates its policy objectives.

3.1 | The monetary authority

The Monetary Rule, *MR*, emerges as:

$$MR: y = -\phi_\pi \pi \quad (10)$$

where ϕ_π corresponds to the monetary reaction parameter. It is given by $\phi_\pi = \frac{1}{\alpha_M} * \frac{\frac{d\pi}{di}}{\frac{dy}{di}}$, where $\frac{d\pi}{di} = \frac{\partial \pi}{\partial y}\frac{dy}{di} + \frac{\partial \pi}{\partial g}\frac{\partial g}{\partial i} + \frac{\partial \pi}{\partial i} = \frac{\partial \pi}{\partial y}\frac{\partial y}{\partial i} + \left(\frac{\partial \pi}{\partial y}\frac{\partial y}{\partial g} + \frac{\partial \pi}{\partial g}\right)\frac{\partial g}{\partial i} + \frac{\partial \pi}{\partial i}$. The first impact is the standard one through AD; the second is the (direct and indirect) one of the union-wide fiscal reaction to monetary policy that is taken into account under monetary leadership, so it disappears under either simultaneous move or fiscal leadership, since the monetary authority considers the union-wide fiscal stance as given ($\frac{\partial g}{\partial i} = 0$); and the third one is the cost-channel effect.[14] The monetary reaction parameter can be found to be given by $\phi_\pi = \frac{1}{\alpha_M} * \left[\omega_y + (1-\delta_y)\frac{\omega_g V_g^{ML} + \omega_i}{\delta_g V_g^{ML} - \delta_r}\right]$, where *ML* stands for Monetary Leadership and $V_g^{ML} = \frac{\partial g}{\partial i}$ vanishes under simultaneous move or fiscal leadership.[15] It can be shown that the sign of $\frac{\partial \phi_\pi}{\partial V_g^{ML}}$ is the opposite of $\delta_g\omega_i + \delta_r\omega_g$, where the latter defines relative policy effectiveness; and being indifferent to zero implies that the two policy instruments are not perfect substitutes in the stabilisation process (see Chortareas & Mavrodimitrakis, 2021).[16] Thus, under perfect instrument substitutability, namely $\delta_g\omega_i + \delta_r\omega_g = 0$, then $\frac{\partial \phi_\pi}{\partial V_g^{ML}} = 0$, which means that the monetary reaction parameter is independent on the strategic and fiscal regimes; hence on country-size asymmetry, too. But in the general case of imperfect instrument substitutability, country-size asymmetry should affect the monetary reaction parameter.

Substituting the monetary rule, Equation (10), in the union-wide PC relation, Equation (4), and substituting for the union-wide output gap, *y*, from the union-wide AD Equation (3), we get the nominal interest rate, *i*, as a function of both the union-wide fiscal stance, *g*, and shock, *u*, as:

$$i = \frac{\frac{\delta_g}{1-\delta_y}\left(\frac{1}{\phi_\pi} + \omega_y\right) + \omega_g}{\frac{\delta_r}{1-\delta_y}\left(\frac{1}{\phi_\pi} + \omega_y\right) - \omega_i} g + \frac{\frac{\delta_u}{1-\delta_y}\left(\frac{1}{\phi_\pi} + \omega_y\right) + \omega_u}{\frac{\delta_r}{1-\delta_y}\left(\frac{1}{\phi_\pi} + \omega_y\right) - \omega_i} u = V_i g + V_u u \tag{11}$$

where $V_i = \frac{\frac{\delta_g}{1-\delta_y}\left(\frac{1}{\phi_\pi} + \omega_y\right) + \omega_g}{\frac{\delta_r}{1-\delta_y}\left(\frac{1}{\phi_\pi} + \omega_y\right) - \omega_i}$ and $V_u = \frac{\frac{\delta_u}{1-\delta_y}\left(\frac{1}{\phi_\pi} + \omega_y\right) + \omega_u}{\frac{\delta_r}{1-\delta_y}\left(\frac{1}{\phi_\pi} + \omega_y\right) - \omega_i}$. In the strategic regimes of either simultaneous move or fiscal leadership, $\frac{\partial i}{\partial g} = V_i^{SM} = \frac{\frac{\delta_g}{1-\delta_y}\left(\frac{1}{\phi_\pi^{SM}} + \omega_y\right) + \omega_g}{\frac{\delta_r}{1-\delta_y}\left(\frac{1}{\phi_\pi^{SM}} + \omega_y\right) - \omega_i}$, where SM stands for Simultaneous Move and $\phi_\pi^{SM} = \frac{1}{\alpha_M} * \left[\omega_y - (1-\delta_y)\frac{\omega_i}{\delta_r}\right]$; which shows that V_i^{SM} is independent on country *j*'s weight, q_j. It is clear that the cost-channel effect, $\omega_i \neq 0$, decreases the monetary reaction parameter, in that in any change in the inflation rate, the monetary authority becomes less reactionary, since now there is a direct opposite effect of the nominal interest rate on inflation. A strong enough cost-channel effect, namely $\omega_i > \frac{\omega_y\delta_r}{1-\delta_y}$, delivers a negative monetary reaction parameter; hence the monetary authority does not trade-off its objectives, since the nominal interest rate becomes a supply-side policy instrument.[17]

3.2 | The national fiscal authorities: The alternative fiscal regimes

We now consider the fiscal authorities' decision-making process under the alternative fiscal regimes. The country-specific fiscal rule for the national fiscal authorities under narrow coordination is given by:

$$g_j = -\alpha_F \frac{dy_j}{dg_j} y_j = -\alpha_F \left[\frac{\partial y_j}{\partial g_j} + \left(\frac{\partial y_j}{\partial g} + \frac{\partial y_j}{\partial i}\frac{\partial i}{\partial g}\right)\frac{\partial g}{\partial g_j}\right] y_j = -\phi_{g_j} y_j \tag{12}$$

where $\phi_{g_j} = \alpha_F\left[Z_{g_j} + q_j\left(Z_g - Z_i V_i^{SM}\right)\right]$ is the country-specific fiscal reaction parameter; and V_i^{SM} is considered only under fiscal leadership, since it vanishes under either simultaneous move or monetary leadership. Averaging the country-specific fiscal rules, given by Equation (12), across all countries provides the union-wide fiscal rule $g = -\alpha_F \sum_{j=1}^{n} \frac{dy_j}{dg_j} q_j y_j = -\alpha_F \left[Z_{g_j} y + \left(Z_g - Z_i V_i^{SM}\right)\sum_{j=1}^{n} q_j^2 y_j\right]$. It is clear that country-size asymmetry matters as long as there are strategically significant (direct or indirect) spill-over effects in the monetary union (Kempf & von Thadden, 2013), defined as $Z_g - Z_i V_i^{SM} \neq 0$; that is, under interconnections ($Z_g \neq 0$) or in the fiscal leadership strategic regime (V_i^{SM} does not vanish).[18] Under those circumstances, if the member-states differ in size, the country-specific fiscal reaction parameters would differ, too, and the union-wide fiscal rule relates the union-wide fiscal stance with the country-specific output gap, along with the union-wide one. Combining the country-specific and union-wide fiscal rules, we can compute the relative output gaps, using Equation (9). It is shown in the Appendix that, as long as there are strategically significant spill-over effects, the strategic regimes, monetary policy and country-size asymmetry should all matter for relative output gaps.

Considering the broad coordination fiscal regime, the first order condition reads for:

$$q_j g_j + \alpha_F \left(q_j \frac{dy_j}{dg_j} y_j + \sum_{k=1, k \neq j}^{n} q_k \frac{dy_k}{dg_j} y_k \right) = 0 \Rightarrow g_j = -\alpha_F \left[Z_{g_j} y_j + \left(Z_g - Z_i V_i^{SM} \right) y \right] \quad (13)$$

where $k \neq j$ defines another (foreign) country. Now, the national fiscal authorities react to possible changes to foreign output gaps, too (so, to the union-wide output gap), as long as there are strategically significant spill-over effects, since $\frac{dy_k}{dg_j} = q_j \left(Z_g - Z_i V_i^{SM} \right)$. Equation (13) shows that country-size asymmetry does not matter, and the same holds at the union level, where the union-wide fiscal stance is related to the union-wide output gap, alone, delivering a union-wide Fiscal Rule, *FR*, of the form:

$$FR: g = -\phi_g y \quad (14)$$

where ϕ_g defines the union-wide fiscal reaction parameter. Specifically, summing up Equation (13) for all member-states, we get: $g = -\alpha_F \left(Z_{g_j} + Z_g - Z_i V_i^{SM} \right) y$; where $\phi_{g_{bc}} = \alpha_F \left(Z_{g_j} + Z_g - Z_i V_i^{SM} \right) = \alpha_F \frac{\delta_g - \delta_r V_i^{SM}}{1 - \delta_y}$ and bc stands for broad coordination; and again V_i^{SM} vanishes under either simultaneous move or monetary leadership. It can be shown that in the fiscal leadership strategic regime, the union-wide fiscal stance is neutral ($\phi_{g_{bc}} = 0$) when the two policy instruments are perfect substitutes in the stabilisation process ($\delta_g \omega_i + \delta_r \omega_g = 0$); and in the general case the union-wide fiscal policy can even become pro–cyclical (Chortareas & Mavrodimitrakis, 2021). Relative output gaps can be computed as in the narrow coordination fiscal regime, and are given by:

$$y_j - y = \frac{1}{1 + \alpha_F Z_{g_j}^2} \left(Z_{u_j} \delta_u - Z_{du} \omega_u \right) \left(u_j - u \right) \quad (15)$$

Equation (15) clearly shows that relative output gaps in the broad coordination fiscal regime are completely independent on monetary policy, the alternative strategic regimes, and on country-size asymmetry.

In the core/periphery fiscal regime, Equation (12) still describes the fiscal rule for the core and the peripheral member-states, but the first derivatives, $\frac{dy_j}{dg_j}$, will differ, not only because of country-size asymmetry, but also because the lead fiscal authority takes into account the followers' reactions to its choice of its fiscal stance; that is, $\frac{\partial g}{\partial g_j}$ is now replaced by $\frac{dg}{dg_l}$, where $\frac{dg}{dg_l} = \frac{\partial g}{\partial g_j} + \sum_{k=1, k \neq l}^{n} \frac{\partial g}{\partial g_k} \frac{\partial g_k}{\partial g_l}$ and the subscript l refers to the lead fiscal authority. The leader's first order condition reads for:

$$\begin{aligned} g_l &= -\alpha_F \frac{dy_l}{dg_l} y_l \\ &= -\left\{ \tilde{\phi}_{g_l} - \alpha_F^2 \left(Z_g - Z_i V_i^{SM} \right)^2 q_l \left[(1 - q_l) Z_{g_j} + \left(Z_g - Z_i V_i^{SM} \right) \sum_{k=1, k \neq l}^{n} q_k^2 \right] \right\} y_l \\ &= -\phi_{g_l} y_l \end{aligned} \quad (16)$$

where the leader's fiscal reaction parameter is given by $\phi_{g_l} = \tilde{\phi}_{g_l} - \alpha_F^2 \left(Z_g - Z_i V_i^{SM} \right)^2 q_l \left[(1 - q_l) Z_{g_j} + \left(Z_g - Z_i V_i^{SM} \right) \sum_{k=1, k \neq l}^{n} q_k^2 \right]$, and $\tilde{\phi}_{g_l} = \alpha_F \left[Z_{g_j} + q_l \left(Z_g - Z_i V_i^{SM} \right) \right]$ is the corresponding one if the l (here, the lead) fiscal authority were to play simultaneously with the rest of the union. The difference $\phi_{g_l} - \tilde{\phi}_{g_l}$ being negative defines a fiscal strategic advantage for the core member-state in that its fiscal authority follows a less counter-cyclical fiscal policy than the one it would have followed being at the periphery. This depends on the existence of strategically significant spill-over effects. E.g., if there are no interconnections, there is no fiscal strategic advantage in the monetary leadership strategic regime, while the strategic advantage increases with the trade effect ($\frac{\partial \left(\left| \phi_{g_l} - \tilde{\phi}_{g_l} \right| \right)}{\partial \delta_y} > 0$).[19] In the fiscal leadership strategic regime, instead, the two fiscal reaction parameters differ even in the absence of interconnections, since the lead fiscal authority can still exploit the peripheral member-states' fiscal authorities by leading the central bank.

To compute the union-wide fiscal rule, we need to sum up Equation (12) with Equation (16), but the former for all the peripheral member-states, excluding the core member-state; namely, $g = -\alpha_F [\sum_{j=1}^{n} q_j \phi_{g_j} y_j - (\tilde{\phi}_{g_l} - \phi_{g_l}) q_l y_l]$. Similar to the narrow coordination fiscal regime, country-size asymmetry matters as long as there are strategically significant spill-over effects, and the union-wide fiscal rule involves the country-specific output gap, too. The latter holds, since the country-specific fiscal reaction parameters differ; in the narrow coordination fiscal regime because of country-size asymmetry, while in the core/periphery regime also because of the asymmetry in the sequence of moves (the fiscal strategic advantage). The relative output gap can be computed as before, for the lead fiscal authority.[20] However, assuming country-size symmetry, namely $q_j (= q_l) = \frac{1}{n}$, the narrow coordination fiscal regime delivers a union-wide fiscal rule of the form given by Equation (14). Specifically, following the country-specific fiscal rule given by Equation (12), $\phi_{g_j} = \phi_{g_{nc}} = \alpha_F \left[Z_{g_j} + \frac{1}{n} \left(Z_g - Z_i V_i^{SM} \right) \right]$, where nc reads for narwrow coordination.

4 | UNION-WIDE AND RELATIVE EQUILIBRIUM SOLUTIONS

In all cases of (i) no strategically significant spill-over effects, or (ii) the broad coordination fiscal regime, or (iii) the narrow coordination fiscal regime under country-size symmetry, a 4×4 system of (log-)linear equations at the union level is created, with unknowns being inflation, the output gap, the fiscal stance, and the common nominal interest rate.[21] The equations are the two descriptive ones at the union level, namely Equations (3) and (4), the monetary rule given by Equation (10) and a fiscal rule given by Equation (14). All these equations entail only union-wide variables and the union-wide shock, u. Thus, at equilibrium, the union-wide macroeconomic variables do not depend on asymmetric shocks; hence the monetary authority reacts only to the union-wide shock, while the burden of stabilising asymmetric shocks lies entirely on the national fiscal authorities (Chortareas & Mavrodimitrakis, 2021). Following the analysis in the previous section (Section 3), country-size asymmetry and the fiscal regimes matter as long as there are strategically significant spill-over effects; in that, when these are absent, the union-wide and country-specific equilibrium solutions are the same across all the alternative fiscal regimes.[22] Moreover, country-size asymmetry plays no role in the stabilisation of shocks in a monetary union when fiscal authorities co-operate (i.e., in the broad coordination fiscal regime).

In order to solve the model and provide the union-wide equilibrium solutions, we assume country-size symmetry and we start from the core/periphery set-up; where solutions for the other fiscal regimes emerge as special cases. The lead fiscal authority's reaction parameter, following Equation (16), is given by $\phi_{g_l}=\phi_{g_{nc}}\left[1-\alpha_F\frac{n-1}{n^2}\left(Z_g-Z_iV_i^{SM}\right)^2\right]$; in which $\phi_{g_{nc}}$ is the peripheral fiscal authorities' reaction parameter. Then, the union-wide fiscal rule can be computed as:

$$g=-\phi_{g_{nc}}y+\frac{1}{n}\left(\phi_{g_{nc}}-\phi_{g_l}\right)y_l \tag{17}$$

where $\phi_{g_{nc}}-\phi_{g_l}=\alpha_F\frac{n-1}{n^2}\left(Z_g-Z_iV_i^{SM}\right)^2\phi_{g_{nc}}$. Equation (17) shows that the union-wide fiscal rule differs from the previous one described by Equation (14) in that it involves the leader's output gap, too, as long as there are strategically significant spill-over effects. Now, the union-wide variables should be solved together with the country-specific ones, following the lead authority's fiscal rule and AD equations, namely Equations (16) and (8), respectively.

We can start with the inflation rate by combining Equations (16) and (8) with Equations (3), (4), (10)–(11) and (17). This gives the following expression:

$$\left\{1+\left[\omega_y-\left(\omega_g+\omega_iV_i\right)\phi_g\right]\phi_\pi\right\}\pi=\left(\omega_g+\omega_iV_i\right)\left(\phi_{g_{nc}}-\phi_{g_l}\right)y_l+\left(\omega_u+\omega_iV_u\right)u \tag{18}$$

Equation (18),[23] although not a closed-form solution for the inflation rate at the union level, since it relates it to the leader's output gap, it is extremely intuitive. If we abstract from the core/periphery set-up and consider, instead, the two alternative fiscal regimes of either narrow or broad coordination, then the fiscal reaction parameter is common for all the national fiscal authorities; so, $\phi_{g_{nc}}=\phi_{g_l}$ and Equation (18) directly becomes a closed-form solution for the inflation rate. In this case, inflation is affected at equilibrium only by the union-wide shock, u; so, asymmetric shocks are fully offset at the union level. Moreover, the cost-channel effect ($\omega_i\neq0$) makes the (union-wide) shock with demand-side effects ($\delta_u\neq0$) not to be fully offset at the union level, since, following Equation (11), V_u is a function of δ_u. In the absence of the cost-channel effect ($\omega_i=0$), only shocks with supply-side effects ($\omega_u\neq0$) affect inflation at the union level (Chortareas & Mavrodimitrakis, 2021). In the core/periphery fiscal regime, however, under strategically significant spill-over effects, the inflation rate at the union level might be affected by asymmetric shocks, since, following the country-specific AD Equation (8), this is the case for the lead fiscal authority's output gap. But this holds only when $\omega_g+\omega_iV_i\neq0$; but $\omega_g+\omega_iV_i=\frac{\left(\delta_g\omega_i+\delta_r\omega_g\right)\frac{1}{1-\delta_y}\left(\frac{1}{\phi_\pi}+\omega_y\right)}{\frac{\delta_r}{1-\delta_y}\left(\frac{1}{\phi_\pi}+\omega_y\right)-\omega_i}$, which vanishes under perfect instrument substitutability; namely, when $\delta_g\omega_i+\delta_r\omega_g=0$. Thus, for the core/periphery set-up to matter at the union level, the two policy instruments should not be perfect substitutes in the stabilisation process; which holds for $\delta_g\omega_i+\delta_r\omega_g\neq0$. Following the monetary rule given by Equation (10), the analysis exactly holds for the union-wide output gap, too.

At equilibrium, the inflation rate can be computed as:

$$\pi=\frac{1}{\Omega}\left\{\left[1+Z_{g_j}\phi_g-\frac{n-1}{n}Z_{g_j}\left(\phi_{g_{nc}}-\phi_{g_l}\right)\right]\left(\omega_i\delta_u+\delta_r\omega_u\right)u+\frac{1}{n}\left(\phi_{g_{nc}}-\phi_{g_l}\right)\left(\delta_g\omega_i+\delta_r\omega_g\right)\left(Z_{u_j}\delta_u-Z_{du}\omega_u\right)\left(u_l-u\right)\right\} \tag{19}$$

where $\Omega=\left\{\delta_r+\left[\delta_r\omega_y-\left(1-\delta_y\right)\omega_i\right]\phi_\pi\right\}\left[1+Z_{g_j}\phi_g-\frac{n-1}{n}Z_{g_j}\left(\phi_{g_{nc}}-\phi_{g_l}\right)\right]-\left(\delta_g\omega_i+\delta_r\omega_g\right)\left[\left(1+Z_{g_j}\phi_g\right)\phi_g+\left(\frac{1}{n}-Z_{g_j}\right.\right.$

$\phi_g)\left(\phi_{g_{nc}}-\phi_{g_l}\right)\Big]\phi_\pi$.[24] First, abstracting from the core/periphery set-up ($\phi_{g_{nc}}=\phi_{g_l}$), following our previous discussion, union-wide shocks with demand-side effects ($\delta_u\neq 0$) affect union-wide macroeconomic variables only if there is a cost-channel effect ($\omega_i\neq 0$). Moreover, there is a special case that union-wide shocks can be fully offset, namely when $\omega_i\delta_u+\delta_r\omega_u=0$. In this case, the common nominal interest rate and the union-wide shock are perfect substitutes, so the monetary authority succeeds in fully offsetting this shock (abstracting from the zero-lower-bound constraint). This can work for supply shocks and shocks that mimic the Covid-19 pandemic, since δ_u and ω_u need to have opposite signs; and by default it is the case for financial shocks, since $\delta_u=-\delta_r$ and $\omega_u=\omega_i$. The cost channel attributes features to monetary policy that are close to supply shocks, since a contractionary monetary policy directly decreases aggregate demand and directly increases inflation; similar to a negative supply shock.

Second, considering the core/periphery set-up, it is clear that asymmetric shocks between the core and the periphery, given by u_l-u, pass through at the union level as long as the two policy instruments are not perfect substitutes in the stabilisation process ($\delta_g\omega_i+\delta_r\omega_g\neq 0$).[25] Thus, in the core/periphery fiscal regime assuming fiscal sequential asymmetries when there are strategically significant spill-over effects ($Z_g-Z_iV_i^{SM}\neq 0$, then $\phi_{g_{nc}}\neq\phi_{g_l}$) together with imperfect instrument substitutability ($\delta_g\omega_i+\delta_r\omega_g\neq 0$), asymmetric shocks between the core and the periphery (u_l-u) pass through to the union-wide inflation ($\frac{\partial\pi}{\partial(u_l-u)}\neq 0$) and the output gap ($\frac{\partial y}{\partial(u_l-u)}\neq 0$). This is the main result of this paper.

To interpret our result, we can compute the union-wide fiscal stance, as:

$$g=-\frac{1}{\Omega}\Bigg\{\Bigg[\left(1+Z_{g_j}\phi_g\right)\phi_g+\left(\frac{1}{n}-Z_{g_j}\phi_g\right)\left(\phi_{g_{nc}}-\phi_{g_l}\right)\Bigg]\phi_\pi(\omega_i\delta_u+\delta_r\omega_u)u+\frac{1}{n}\left(\phi_{g_{nc}}-\phi_{g_l}\right)\lambda\left(Z_{u_j}\delta_u-Z_{du}\omega_u\right)(u_l-u)\Bigg\}\tag{20}$$

where $\lambda=\delta_r+\left[\delta_r\omega_y-\left(1-\delta_y\right)\omega_i\right]\phi_\pi$. Equation (20) shows that the union-wide fiscal stance is also affected by asymmetric shocks at equilibrium, but this is independent on relative policy effectiveness; that is, it also holds under perfect instrument substitutability (Hughes Hallett & Mavrodimitrakis, 2019). This is so, since the fiscal reaction parameters differ, implying asymmetric fiscal reactions that do not cancel out at the union level; hence affecting both the output gap and the inflation rate at the union level, too. In turn, the monetary authority reacts to this asymmetry. If the two policy instruments are perfect substitutes in the stabilisation process, the monetary authority succeeds in matching this asymmetry's impact on the union-wide output gap and the inflation rate; but this does not hold under imperfect instrument substitutability, where the two policy instruments differ in their relative effectiveness.[26] The monetary authority will also share the burden of stabilising those shocks with the national fiscal authorities.[27]

Finally, we can compute the relative output gap for the lead fiscal authority,[28] as:

$$y_l-y=\frac{1}{1+Z_{g_j}\phi_{g_{nc}}}\frac{1}{\Omega}\Bigg\{\frac{n-1}{n}\left(\phi_{g_{nc}}-\phi_{g_l}\right)Z_{g_j}\mu(\omega_i\delta_u+\delta_r\omega_u)u+\left[\Omega_{nc}-\frac{1}{n}\left(\phi_{g_{nc}}-\phi_{g_l}\right)\left(\delta_g\omega_i+\delta_r\omega_g\right)\mu\right]\left(Z_{u_j}\delta_u-Z_{du}\omega_u\right)(u_l-u)\Bigg\}\tag{21}$$

where $\mu=\left(1-Z_{g_j}\phi_{g_{nc}}\right)\phi_\pi$, and $\Omega_{nc}=\left(1+Z_{g_j}\phi_{g_{nc}}\right)\{\delta_r+\left[\delta_r\omega_y-\left(1-\delta_y\right)\omega_i\right]\phi_\pi-\left(\delta_g\omega_i+\delta_r\omega_g\right)\phi_{g_{nc}}\phi_\pi\}$ defines the *reference parameter* under narrow coordination. It is clear from Equation (21) that in the core/periphery fiscal regime the relative output gap for the lead fiscal authority is also affected by union-wide shocks, together with asymmetric ones, since the fiscal authrities' reactions are now asymmetric. The monetary authority does react to these asymmetries, but in a way to stabilise union-wide macroeconomic variables; hence exacerbating core/periphery imbalances. A portion of the union-wide shock affects member-states asymmetrically at equilibrium (see also Hughes Hallett & Mavrodimitrakis, 2019). Regarding asymmetric shocks, when the two policy instruments are perfect substitutes ($\delta_g\omega_i+\delta_r\omega_g=0$), the monetary policy succeeds in offsetting them, so their impact on relative output gaps is exactly the same as in the fiscal regime of narrow coordination. However, this does not hold in the general case that the policy instruments are not perfect substitutes ($\delta_g\omega_i+\delta_r\omega_g\neq 0$), where the impact of asymmetric shocks on relative output gaps differs, since we saw that monetary policy is not successful. Abstracting from the core/periphery set-up, the member-states in the monetary union share the stabilisation burden. In the narrow coordination fiscal regime, a larger monetary union widens the gap, while monetary policy matters only in the fiscal leadership strategic regime (Chortareas & Mavrodimitrakis, 2021).

5 | CONCLUSIONS

This paper utilises a standard static reduced-form neo-Keynesian model of a monetary union to capture the strategic fiscal/monetary policy interactions and explore the stabilisation share of asymmetric shocks among the authorities involved. The model assumes a multi-country setting of country-size asymmetry, strategically significant spill-over effects among member-states and supply-side effects of policies, and considers all possible strategic regimes (fiscal/monetary leadership; simultaneous moves) together with three alternative fiscal regimes (narrow/broad coordination; core/periphery set-up). The main results can be summarised as follows: (i) in the cases of no strategically significant spill-over effects, broad coordination, and narrow coordination under country-size symmetry, all union-wide macroeconomic variables are only affected by union-wide shocks and not by shocks' asymmetries, so the national fiscal authorities share the burden of shocks' stabilisation; (ii) country-size asymmetry does not matter in the broad coordination fiscal regime and when there are no strategically significant spill-over effects (since the alternative fiscal regimes do not matter); and (iii) in the core/periphery fiscal regime under country-size symmetry, asymmetric shocks between the core and the peripheral member-states pass through at the union level, affecting both the inflation rate and the output gap, while union-wide (even common) shocks deliver differing country-specific output demans, creating imbalances.

To the best of our knowledge, this is the first paper in the literature that shows how asymmetric shocks pass through at the union level, providing closed-form (analytical) equilibrium solutions in an otherwise symmetric monetary union (excluding fiscal sequential asymmetries). Asymmetric shocks give rise to asymmetric fiscal reactions, resulting in a non-neutral union-wide fiscal stance; hence inducing a monetary reaction. If the two policy instruments are not perfect substitutes in the stabilisation process, then the monetary authority cannot fully offset those fiscal reactions, and shocks' asymmetries pass through at the union level. Relative output gaps between the core and the rest of the union are now affected by union-wide shocks, too, and the impact of asymmetric shocks on relative output gaps differs from the corresponding one under narrow coordination. In a strategic context, the main assumptions responsible for this result are (i) the existence of strategically significant spill-over effects; (ii) fiscal sequential asymmetries; and (iii) imperfect instrument substitutability.

In an attempt to discuss the policy implications of this exercise, the monetary authority's first best would be to induce fiscal authorities' cooperation when facing asymmetric shocks, since under either narrow or broad coordination those do not pass through at the union level. A second best, instead, entails cases that minimise the impact of the core/periphery set-up, increasing the effectiveness of the monetary policy's instrument on asymmetric shocks; specifically, (i) when the impact of strategically significant spill-over effects is small, and (ii) when the degree of substitutability of the two policy instruments is high. The former can be induced by the fiscal leadership strategic regime, especially when the direct spill-over effects (namely, the interconnections) are nontrivial, since this weakens the asymmetric fiscal reactions, providing a form of implicit coordination among the authorities (Hughes Hallett & Weymark, 2007). The latter can be induced by incentivising the fiscal authorities to use policy instruments that directly affect inflation negatively when fiscal policy is expansionary, like taxes, production subsidies, or public investment, especially if there exists a non-trivial cost-channel effect, since the monetary and fiscal policies' instruments become substitutes; namely, an expansionary monetary/fiscal policy directly increases aggregate demand and directly decreases inflation.

Further considerations might include unconventional monetary policy, fiscal sustainability, and fiscal transfers. We leave all that to future research.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

ENDNOTES

[1] Various references can be found there, together with their assumptions/results/policy implications, since the authors essentially provide a unified framework to this literature.

[2] In what follows, we also explore the limiting case of no strategically significant spill-over effects as a mere theoretical case, exactly in order to highlight the implications of the assumption of strategically significant spill-over effects.

[3] Kirsanova et al. (2018) consider the endogenous decision between two fiscal authorities in a monetary union to play sequentially, using a two-country Dynamic Stochastic General Equilibrium (DSGE) model, finding that such equilibria could arise.

[4] Gali and Monacelli (2008) provide micro-foundations for a direct negative effect in a monetary union; see also Palek and Schwanebeck (2017) and Vieira et al. (2018).

[5] The presence of the cost channel of monetary policy provides an alternative interpretation of the price puzzle; that is, the observation that a contractionary monetary policy shock is followed by a rise in the price level (Walsh, 2017). See also footnote 17, below. Further empirical evidence on the cost channel can be found in Gaiotti and Secchi (2006), Chowdhury et al. (2006), and Henzel et al. (2009).

[6] In Chortareas and Mavrodimitrakis (2021), it is shown how to derive a relation between the loan rate and the common nominal interest rate by explicitly considering banks' behaviour under imperfect competition, and the implications for both the cost-channel effect and for cost-push shocks.

[7] The existence of a cost channel of monetary policy makes financial shocks have cost-push effects, too; so, they are not captured by pure negative demand shocks.

[8] In the EMU's context, this is consistent with both the Stability and Growth Pact and the Fiscal Compact, as well as with more recent developments.

[9] Microeconomic foundations for Equation (6) are provided by Andersen and Spange (2006). The authors show that this particular loss function can be derived from a representative household's utility function in the usual way that depends positively on private consumption and the provision of public goods, and negatively on labour supply, where the private consumption bundle is defined over the consumption of domestic and foreign commodities.

[10] We thank an anonymous referee for their recommendation to include such a table.

[11] Thus, the core/periphery set-up can only be considered in the two leadership strategic regimes. For alternative specifications in a two-country model, see Hughes Hallett and Mavrodimitrakis (2019).

[12] Both the elasticities of domestic and foreign (union-wide) fiscal policy on domestic aggregate demand, namely Z_{g_j} and Z_g, respectively, are unambiguously positive when the fiscal stance is a demand-side policy instrument.

[13] Country-specific and union-wide expected inflation rates are not included, since they are both equal to zero.

[14] Monetary leadership is recently considered by Canofari et al. (2021), capturing active monetary policies towards a financial-stability objective. See also Canofari et al. (2022).

[15] We need the fiscal rules to compute this. The corresponding expressions for all the fiscal regimes can be found in the Appendix.

[16] Details can be found in the Appendix.

[17] This implies a price puzzle. A demand-side policy instrument in the absence of a price puzzle assumes $\omega_y\delta_r - \omega_i > 0$.

[18] If the monetary reaction to the union-wide fiscal stance is positive, namely $V_i^{SM} > 0$, and in the fiscal leadership regime this is taken into consideration by the fiscal authorities, then there might be a (special) case that the negative impact of monetary policy on aggregate demand exactly offsets the positive impact from the interconnections; namely, $Z_g = Z_i V_i^{SM}$.

[19] This is consistent with Hughes Hallett and Mavrodimitrakis (2019) for a lead and a follower fiscal authority in a two-country monetary union under country-size symmetry.

[20] Relative output gaps for both the narrow coordination and the core/periphery fiscal regimes are shown in the Appendix.

[21] Recall that expected inflation is equal to zero.

[22] This limiting case is presented in the Appendix.

[23] Two points are worth mentioning: (i) in the monetary leadership strategic regime, the monetary reaction parameter, ϕ_π, is a function of $V^{ML}_{g_{c/p}} = V^{ML}_{g_{nc}}\left(1-\alpha_F\frac{n-1}{n^3}Z_g^2\right)$, where c/p stands for core/periphery; and (ii) V_i is susceptible to the strategic regimes, where $V_i^{ML} \neq V_i^{SM}$ since $\phi_\pi^{ML} \neq \phi_\pi^{SM}$.

[24] We call Ω the *reference parameter*, since it 'refers' to a specific institutional arrangement; hence capturing differences in the equilibrium solutions of the union-wide macroeconomic variables across the strategic and fiscal regimes. The union-wide output gap can be computed by using the monetary rule, Equation (10). The equilibrium solution can be found in the Appendix. Moreover, tables A1 and A2 in the Appendix present the reaction and reference parameters in all the alternative strategic and fiscal regimes; hence providing the equilibrium solutions. There, one can also find the equilibrium solutions in the absence of the core/periphery set-up, so for the narrow/broad coordination fiscal regimes, which follow Chortareas and Mavrodimitrakis (2021).

[25] Recall from the country-specific AD Equation (8) and the relative output gaps Equation (9) that the pre-requisite is for country-specific shocks to affect aggregate demand; namely, $Z_{u_j}\delta_u - Z_{du}\omega_u \neq 0$.

[26] Equation (20) holds for all the alternative fiscal regimes by replacing ϕ_{g_l} with ϕ_g, when $\phi_{g_{nc}} = \phi_{g_l}$.

[27] Naturally, all shocks' asymmetries pass through, even if their union-wide counter-parts do not; for example, demand-side effects even in the absence of a cost-channel effect, or financial shocks.

[28] The common nominal interest rate can be computed by substituting for the equilibrium union-wide fiscal stance, Equation (20), in the monetary authority's reaction function, Equation (11). The equilibrium solution can be found in the Appendix.

[29] The process is explained in the Appendix, where one can also find the relative output gaps for the narrow coordination fiscal regime, obtained from Equation (21) by setting $\phi_{g_{nc}} = \phi_{g_l}$; for the broad coordination one, they are given by Equation (15), above.

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APPENDIX

We discuss imperfect instrument substitutability and relative policy effectiveness, following Chortareas and Mavrodimitrakis (2021). Using the union-wide descriptive Equations (3) and (4), we can compute the derivative $-\frac{d\pi}{dy}$ for both policy instruments, which measures the impact on inflation of a marginal change in the output gap induced by the corresponding authority that controls the specific policy instrument. These are given by $-\frac{d\pi}{dy}=\frac{\frac{\partial\pi}{\partial i}}{\frac{\partial y}{\partial i}}=\omega_y-\frac{(1-\delta_y)\omega_i}{\delta_r}$ and $-\frac{d\pi}{dy}=\frac{\frac{\partial\pi}{\partial g}}{\frac{\partial y}{\partial g}}=\omega_y+\frac{(1-\delta_y)\omega_g}{\delta_g}$ for the

monetary policy's and the (union-wide) fiscal policy's instruments (namely, the union-wide fiscal stance, g), respectively, and define the marginal rates of transformation between union-wide inflation and output gap for monetary and union-wide fiscal policy, respectively. If the policy instruments are demand/supply-sided, then the two derivatives are positive/negative, and the two policy instruments are substitutes; whereas if they differ in sign, which means that the one is demand-sided and the other supply-sided, then the two policy instruments are complements. If they are equal (in absolute terms), then this implies perfect substitutability/complementarity. In general, the relation between those derivatives assumes the degree of substitutability between the policy instruments, and defines relative policy effectiveness; that is, how much more effective is one policy instrument in stabilising the one target variable relative to the other than the other policy instrument. Thus, perfect substitutability implies $\delta_g\omega_i+\delta_r\omega_g=0$; which basically assumes policy instruments that are linearly dependent.

The union-wide fiscal rule in the core/periphery fiscal regime can be computed by summing up Equation (12) with Equation (16), but the former for all the peripheral member-states. We end up with:

$$g=-\alpha_F\left\{Z_{g_j}y+\left(Z_g-Z_iV_i^{SM}\right)\sum_{j=1}^{n}q_j^2y_j-\alpha_F\left(Z_g-Z_iV_i^{SM}\right)^2 q_l^2\left[(1-q_l)Z_{g_j}+\left(Z_g-Z_iV_i^{SM}\right)\sum_{k=1,k\neq l}^{n}q_k^2\right]y_l\right\} \quad \text{(A1)}$$

which adds to the corresponding one from the narrow coordination fiscal regime a (negative) parameter on the core country's aggregate demand.

We can compute relative output gaps for the narrow coordination and the core/periphery fiscal regimes. Combining the country-specific and union-wide fiscal rules in the narrow coordination fiscal regime, namely Equation (12) and $g=-\alpha_F\left[Z_{g_j}y+\left(Z_g-Z_iV_i^{SM}\right)\sum_{j=1}^{n}q_j^2y_j\right]$, and using Equation (9), we get:

$$y_j-y=\frac{1}{1+\alpha_FZ_{g_j}^2}\left[-\alpha_FZ_{g_j}\left(Z_g-Z_iV_i^{SM}\right)\left(q_jy_j-\sum_{j=1}^{n}q_j^2y_j\right)+\left(Z_{u_j}\delta_u-Z_{du}\omega_u\right)\left(u_j-u\right)\right] \quad \text{(A2)}$$

For the core/periphery fiscal regime, we use Equations (12), (16), (9) and (A2). We get:

$$y_l-y=\frac{\alpha_FZ_{g_j}\left(Z_g-Z_iV_i^{SM}\right)}{1+\alpha_FZ_{g_j}^2}\left\{\sum_{k=1,k\neq l}^{n}q_k^2y_k-\left[1-\alpha_F\left(Z_g-Z_iV_i^{SM}\right)\nu\right]q_l(1-q_l)y_l\right\}+\frac{Z_{u_j}\delta_u-Z_{du}\omega_u}{1+\alpha_FZ_{g_j}^2}\left(u_l-u\right) \quad \text{(A3)}$$

where $\nu=(1-q_l)Z_{g_j}+\left(Z_g-Z_iV_i^{SM}\right)\sum_{k=1,k\neq l}^{n}q_k^2$. To compute Equation (21), we evaluate Equation (A3) under country-size symmetry, and then we substitute y_l from Equation (18); and finally we plug in the equilibrium solution for the inflation rate, Equation (19). In the narrow coordination fiscal regime, Equation (21) becomes:

$$y_j-y=\frac{1}{1+Z_{g_j}\phi_{g_{nc}}}\left(Z_{u_j}\delta_u-Z_{du}\omega_u\right)\left(u_j-u\right) \quad \text{(A4)}$$

while relative output gaps in the broad coordination fiscal regime, described by Equation (15), can be obtained by simply replacing $\phi_{g_{nc}}$ with $\alpha_FZ_{g_j}$.

In the monetary leadership regime, $V_g=\frac{dg}{di}$ needs to be computed for all the alternative fiscal regimes; namely, V_g^{SM}, since this is the one that affects the monetary reaction parameter, following Equation (10). Country-specific and union-wide fiscal rules are combined, since $\frac{dg}{di}=\frac{\partial g}{\partial y}\frac{dy}{di}+\frac{\partial g}{\partial y_j}\frac{dy_j}{di}$. We find: $V_{g_{nc}}^{ML}=\frac{\alpha_F\delta_r}{1-\delta_y}\left(Z_{g_j}+Z_g\sum_{j=1}^{n}q_j^2\right)$; $V_{g_{bc}}^{ML}=\frac{\alpha_F\delta_g\delta_r}{(1-\delta_y)^2}$; and $V_{g_{c/p}}^{ML}=\frac{\alpha_F\delta_r}{1-\delta_y}\left\{Z_{g_j}+Z_g\sum_{j=1}^{n}q_j^2-\alpha_FZ_g^2q_l^2\left[(1-q_l)Z_{g_j}+Z_g\sum_{k=1,k\neq l}^{n}q_k^2\right]\right\}$. In the case of no interconnections, then $V_g^{ML}=\alpha_F\delta_g\delta_r$ for all the alternative fiscal regimes. Assuming, instead, country-size symmetry, we find: $V_{g_{nc}}^{ML}=Z_i\phi_{g_{nc}}^{SM}$; $V_{g_{bc}}^{ML}=Z_i\phi_{g_{bc}}^{SM}$; and $V_{g_{c/p}}^{ML}=Z_i\left[\phi_{g_{nc}}^{SM}-\frac{1}{n}\left(\phi_{g_{nc}}^{SM}-\phi_{g_l}^{ML}\right)\right]=V_{g_{nc}}^{ML}\left(1-\alpha_F\frac{n-1}{n^3}Z_g^2\right)$; where the fiscal reaction parameters can be found in Table A1, below. Thus, country-size asymmetry or the size of the union (the number of countries) affect the monetary reaction parameter, as long as the two policy instruments are not perfect substitutes in the stabilisation process, since the sign of $\frac{\partial\phi_g}{\partial V_g^{ML}}$ is the opposite of $\delta_g\omega_i+\delta_r\omega_g$; and $\frac{\partial\phi_g}{\partial V_g^{ML}}=0$ when $\delta_g\omega_i+\delta_r\omega_g=0$.

We can consider the limiting case of no strategically significant spill-over effects. In particular, we assume no interconnections, namely $\delta_y = \delta_\tau = 0$, which implies $Z_g = Z_u = Z_{du} = 0$, and no fiscal leadership, which means that V_i^{SM} in the fiscal reaction parameters given by Equations (12), (13) and (16) vanishes. Then, country-size asymmetry does not matter and all the country-specific and union-wide fiscal reaction parameters are equal under the alternative fiscal regimes. Specifically: $\phi_{g_j} = \phi_g = \alpha_F \delta_g$; and the union-wide fiscal rule follows Equation (14). Recall also that $Z_{g_j} = \delta_g$ and $Z_i = \delta_r$; and $Z_{u_j} = 1$. Substituting the fiscal rules in the relative output gaps in Equation (9), we compute the equilibrium relative output gaps, as:

$$y_j - y = \frac{1}{1 + \alpha_F \delta_g^2} \delta_u (u_j - u) \tag{A5}$$

Thus, member-states share the burden of stabilising the cycle when shocks have demand-side effects, while country-size asymmetry does not matter in the sharing; and the same holds for the strategic and fiscal regimes.

We can compute the equilibrium solutions for the union-wide output gap and the common nominal interest rate. Combining the equilibrium solution for the inflation rate, Equation (19), with the monetary rule, Equation (10), we can obtain the output gap, as:

$$y = -\frac{\phi_\pi}{\Omega} \left\{ \left[1 + Z_{g_j} \phi_g - \frac{n-1}{n} Z_{g_j} \left(\phi_{g_{nc}} - \phi_{g_l} \right) \right] (\omega_i \delta_u + \delta_r \omega_u) \right.$$
$$\left. u + \frac{1}{n} \left(\phi_{g_{nc}} - \phi_{g_l} \right) (\delta_g \omega_i + \delta_r \omega_g) (Z_{u_j} \delta_u - Z_{du} \omega_u) (u_l - u) \right\} \tag{A6}$$

Combining the equilibrium solution for the union-wide fiscal stance, Equation (20), and the monetary authority's reaction function, Equation (11), we can compute the common nominal interest rate as:

$$i = -\frac{1}{\Omega} \left[\left(1 + Z_{g_j} \phi_g \right) \phi_g + \left(\frac{1}{n} - Z_{g_j} \phi_g \right) \left(\phi_{g_{nc}} - \phi_{g_l} \right) \right]$$
$$\phi_\pi \left[V_i (\omega_i \delta_u + \delta_r \omega_u) + V_u (\delta_g \omega_i + \delta_r \omega_g) \right] u$$
$$+ \frac{1}{\Omega} \lambda \left[1 + Z_{g_j} \phi_g - \frac{n-1}{n} Z_{g_j} \left(\phi_{g_{nc}} - \phi_{g_l} \right) \right] V_u u - \frac{1}{\Omega} \frac{1}{n}$$
$$\left(\phi_{g_{nc}} - \phi_{g_l} \right) \lambda V_i (Z_{u_j} \delta_u - Z_{du} \omega_u) (u_l - u) \tag{A7}$$

In the absence of the core/periphery set-up, the equilibrium solution for the inflation rate at the union level can be found by simply setting $\phi_{g_{nc}} = \phi_{g_l}$ in Equation (19). We get:

TABLE A1 The reaction parameters under the alternative strategic and fiscal regimes.

Regimes		Reaction parameters	
Strategic	**Fiscal**	ϕ_π	ϕ_y
SM	NC		$\alpha_F \left(Z_{g_j} + \frac{1}{n} Z_g \right)$
	BC		$\frac{\alpha_F \delta_g}{1 - \delta_y}$
FL	NC	$\frac{1}{\alpha_M} \left(\omega_y - \frac{\omega_i}{Z_i} \right)$	$\alpha_F \left[Z_{g_j} + \frac{1}{n} \left(Z_g - Z_i V_i^{SM} \right) \right]$
	BC		$\alpha_F \frac{\delta_g - \delta_r V_i^{SM}}{1 - \delta_y}$
	C/P		$\phi_g = \phi_{g_{nc}}^{FL};\ \phi_{g_l} = \phi_{g_{nc}}^{FL} \left[1 - \alpha_F \frac{n-1}{n^2} \left(Z_g - Z_i V_i^{SM} \right)^2 \right]$
ML	NC	$\frac{1}{\alpha_M} \left[\omega_y + \left(1 - \delta_y \right) \frac{\omega_g Z_i \phi_{g_{nc}}^{SM} + \omega_i}{\delta_g Z_i \phi_{g_{nc}}^{SM} - \delta_r} \right]$	$\alpha_F \left(Z_{g_j} + \frac{1}{n} Z_g \right)$
	BC	$\frac{1}{\alpha_M} \left[\omega_y + \left(1 - \delta_y \right) \frac{\omega_g Z_i \phi_{g_{bc}}^{SM} + \omega_i}{\delta_g Z_i \phi_{g_{bc}}^{SM} - \delta_r} \right]$	$\frac{\alpha_F \delta_g}{1 - \delta_y}$
	C/P	$\frac{1}{\alpha_M} \left[\omega_y + \left(1 - \delta_y \right) \frac{\omega_g Z_i \phi_{g_{nc}}^{SM} \left(1 - \frac{n-1}{n^3} \alpha_F Z_g^2 \right) + \omega_i}{\delta_g Z_i \phi_{g_{nc}}^{SM} \left(1 - \frac{n-1}{n^3} \alpha_F Z_g^2 \right) - \delta_r} \right]$	$\phi_g = \phi_{g_{nc}}^{ML};\ \phi_{g_l} = \phi_{g_{nc}}^{ML} \left(1 - \alpha_F \frac{n-1}{n^2} Z_g^2 \right)$

TABLE A2 The reference parameter under the alternative strategic and fiscal regimes.

Regimes		
Strategic	**Fiscal**	**Reference parameters, Ω**
SM	NC	$\left(1+Z_{g_j}\phi^{SM}_{g_{nc}}\right)\left\{\delta_r+\left[\delta_r\omega_y-\left(1-\delta_y\right)\omega_i\right]\phi^{SM}_{\pi}-\left(\delta_g\omega_i+\delta_r\omega_g\right)\phi^{SM}_{g_{nc}}\phi^{SM}_{\pi}\right\}$
	BC	$\left(1+Z_{g_j}\phi^{SM}_{g_{bc}}\right)\left\{\delta_r+\left[\delta_r\omega_y-\left(1-\delta_y\right)\omega_i\right]\phi^{SM}_{\pi}-\left(\delta_g\omega_i+\delta_r\omega_g\right)\phi^{SM}_{g_{bc}}\phi^{SM}_{\pi}\right\}$
FL	NC	$\left(1+Z_{g_j}\phi^{FL}_{g_{nc}}\right)\left\{\delta_r+\left[\delta_r\omega_y-\left(1-\delta_y\right)\omega_i\right]\phi^{SM}_{\pi}-\left(\delta_g\omega_i+\delta_r\omega_g\right)\phi^{FL}_{g_{nc}}\phi^{SM}_{\pi}\right\}$
	BC	$\left(1+Z_{g_j}\phi^{FL}_{g_{bc}}\right)\left\{\delta_r+\left[\delta_r\omega_y-\left(1-\delta_y\right)\omega_i\right]\phi^{SM}_{\pi}-\left(\delta_g\omega_i+\delta_r\omega_g\right)\phi^{FL}_{g_{bc}}\phi^{SM}_{\pi}\right\}$
	C/P	$\left[1+Z_{g_j}\phi^{FL}_{g_{nc}}-\frac{n-1}{n}Z_{g_j}\left(\phi^{FL}_{g_{nc}}-\phi^{FL}_{g_l}\right)\right]\left\{\delta_r+\left[\delta_r\omega_y-\left(1-\delta_y\right)\omega_i\right]\phi^{SM}_{\pi}\right\}-\left(\delta_g\omega_i+\delta_r\omega_g\right)\left[\left(1+Z_{g_j}\phi^{FL}_{g_{nc}}\right)\phi^{FL}_{g_{nc}}+\left(\frac{1}{n}-Z_{g_j}\phi^{FL}_{g_{nc}}\right)\left(\phi^{FL}_{g_{nc}}-\phi^{FL}_{g_l}\right)\right]\phi^{SM}_{\pi}$
ML	NC	$\left(1+Z_{g_j}\phi^{SM}_{g_{nc}}\right)\left\{\delta_r+\left[\delta_r\omega_y-\left(1-\delta_y\right)\omega_i\right]\phi^{ML}_{\pi_{nc}}-\left(\delta_g\omega_i+\delta_r\omega_g\right)\phi^{SM}_{g_{nc}}\phi^{ML}_{\pi_{nc}}\right\}$
	BC	$\left(1+Z_{g_j}\phi^{SM}_{g_{bc}}\right)\left\{\delta_r+\left[\delta_r\omega_y-\left(1-\delta_y\right)\omega_i\right]\phi^{ML}_{\pi_{bc}}-\left(\delta_g\omega_i+\delta_r\omega_g\right)\phi^{SM}_{g_{bc}}\phi^{ML}_{\pi_{bc}}\right\}$
	C/P	$\left[1+Z_{g_j}\phi^{SM}_{g_{nc}}-\frac{n-1}{n}Z_{g_j}\left(\phi^{SM}_{g_{nc}}-\phi^{ML}_{g_l}\right)\right]\left\{\delta_r+\left[\delta_r\omega_y-\left(1-\delta_y\right)\omega_i\right]\phi^{ML}_{\pi_{c/p}}\right\}-\left(\delta_g\omega_i+\delta_r\omega_g\right)\left[\left(1+Z_{g_j}\phi^{SM}_{g_{nc}}\right)\phi^{SM}_{g_{nc}}+\left(\frac{1}{n}-Z_{g_j}\phi^{SM}_{g_{nc}}\right)\left(\phi^{SM}_{g_{nc}}-\phi^{ML}_{g_l}\right)\right]\phi^{ML}_{\pi_{c/p}}$

$$\pi=\frac{1}{\Omega}\left(\omega_i\delta_u-\delta_r\omega_u\right)u \tag{A8}$$

where $\Omega=\delta_r+\left[\delta_r\omega_y-\left(1-\delta_y\right)\omega_i\right]\phi_\pi-\left(\delta_g\omega_i+\delta_r\omega_g\right)\phi_g\phi_\pi$. Equation (A8) holds for all the alternative strategic regimes and for the fiscal regimes of narrow and broad coordination; and follows Chortareas and Mavrodimitrakis (2021).

Tables A1 and A2, above, present the reaction parameters and the reference parameter, respectively, for all combinations of strategic and fiscal regimes under country-size symmetry. These can be used in the equilibrium solutions described by Equations (19)–(21); and in Equations (A6)–(A7) (and in (A8)).