Department of Economics

Group for Economic Analysis at Reading (GEAR)

The Policy Mix in a Monetary Union: Who Bears the Burden of Asymmetric Shocks' Stabilisation?

by Christos Mavrodimitrakis

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Department of Economics
University of Reading
Whiteknights
Reading
RG6 6AA
United Kingdom

www.reading.ac.uk

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Christos Mavrodimitrakis*

University of Reading

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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 when there are strategically significant spill-over effects and the monetary policy's and fiscal policy's 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 might be achieved by the fiscal leadership strategic regime (a form of implicit coordination), when there are strong interconnections in the union, and/or inducing the fiscal authorities to use fiscal policy instruments that directly decrease inflation, such as taxes, production subsidies or public investment, when there is a strong cost channel of monetary policy.

Keywords: Monetary union; Strategic interactions; Policy mix; Core/periphery set-up; Asymmetric shocks.
JEL Classification: E52, E61, E62, E63, F45.

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 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 extent the model by Chortareas and Mavrodimitrakis (2021) for a multi-country setting under country-size asymmetry, considering also fiscal sequential asymmetries (see, e.g., Kirsanova, Machado, and Ribeiro (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 that face asymmetric shocks would be worse off in a monetary union. Empirical evidence support the importance of asymmetric shocks as the main source of heterogeneity in the EMU (Jondeau and Sahuc 2008); and strong shock asymmetries between the core and the periphery have been detected (Pentecôte and 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) found 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) interaction between them and with monetary policy becomes crucial for the policy 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 can alter the policy games, having an impact on the policy mix and coordination problems in a monetary union. In particular, Chortareas and Mavrodimitrakis (2021) have shown how the policy mix and coordination problems depend on relative policy effectiveness and the leadership regimes, when the two policy instruments, namely

*University of Reading, School of Politics, Economics and International Relations, Department of Economics, Edith Morley Building, Room 192, Whiteknights Campus, RG6 6UR, Berkshire, UK. Tel: +44 (0)118 378 4671; email: c.mavrodimitrakis@reading.ac.uk.

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] In general, two standard fiscal regimes are considered, namely the narrow (non-cooperative Nash) and broad (cooperative Nash) coordination ones, following Von Hagen and Mundschenk (2003). A common result of this literature is that, at equilibrium, union-wide macroeconomic variables are only affected by union-wide shocks, and not by shocks' asymmetries; hence the stabilisation burden lies entirely on the national fiscal authorities, where its distribution is being determined; and relative output gaps differ. We show that this result does not hold in a core/periphery set-up when asymmetries in the sequence of moves of the fiscal authorities in the union are combined with imperfect instrument substitutability, under strategically significant spill-over effects. To be precise, the combination of those assumptions, namely (i) the existence of strategically significant spill-over effects, (ii) imperfect instrument substitutability, and (iii) fiscal sequential asymmetries, 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. The monetary authority reacts to asymmetric shocks, but cannot succeed in fully offsetting them. 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, 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,[2] 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, excluding the broad coordination fiscal regime; (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 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 logic is the following: asymmetric shocks induce asymmetric fiscal reactions, since there are strategically significant spill-over effects, resulting in the union-wide fiscal stance being 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 if the policy instruments are not perfect substitutes in the stabilisation process.

The structure of the paper is as follows: Section 2 presents the model; 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:

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

$$\pi_j = \pi_j^e + \omega_y y_j + \omega_g g_j + \omega_i i + \omega_u u_j \tag{2}$$

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 represents fiscal policy, captured by the overall fiscal stance. The variable $\bar{r}_j$ 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 and Tamborini 2020).

All 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 between the two countries; that is, the effect of competitiveness on domestic output

[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] Kirsanova, Machado, and Ribeiro (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.

and the relative openness of the economy, respectively. In the PC relation, its slope parameter, ω_y, is positive, and captures nominal (price/wage) rigidities in the economy. 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, while ω_i is positive, and captures the cost-channel effect, following mainly Ravenna and Walsh (2006). Simply put, monopolistically competitive firms must borrow from a financial intermediary to pay for wages in advance; hence prices set by firms directly depend on the cost of borrowing (the loan rate), which here it is assumed to be equal to the common nominal interest rate set by the monetary authority in the union. 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; i.e., $\frac{\partial \pi_j}{\partial g_j} = \omega_g + \omega_y \delta_g > 0$ 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.[3]

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 decrease social distancing, hence the spread of the virus, have a negative impact on aggregate demand, 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 et al. (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 $\frac{\partial \pi_j}{\partial u_j} = \delta_u \omega_y + \omega_u < 0$. 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 $\omega_u = \omega_i > 0$.[4]

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

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

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

where the trade effect, δ_y, works as a multiplier, since increases in either domestic or foreign aggregate demand initiate consequent increases in domestic aggregate demand, 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 and are given by:

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

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

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. In brief, the common central bank in the union follows a flexible inflation-targeting approach and the national fiscal authorities care about the fiscal stance, being constrained by the Fiscal Compact. 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 (see, e.g., Uhlig (2002), Andersen (2008), Chortareas and Mavrodimitrakis (2021); among others).

The time context begins with the private sector forming expectations about future inflation rationally; then, the shock is 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 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 and the central bank follows, while in the monetary leadership strategic regime the monetary authority leads the game and the national fiscal authorities follow. The above time context guarantees that policies are time-consistent; hence $\pi_j^e = \pi^e = 0$ (see, e.g., Uhlig (2002); Andersen (2008); 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,

[3] More details on the model and the structural equations can be found in the exact paper by Chortareas and Mavrodimitrakis (2021).

[4] 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.

where they minimise a joint loss function; 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), and they constitute the periphery of the union. The loss function for horizontal coordination is given by:

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

None alternative regimes with the monetary authority playing between some or cooperate with any of the national fiscal authorities are allowed.[5]

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

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

where the (semi-)elasticities are given by: $Z_i = \frac{\delta_r}{1-\delta_y}$; $Z_{g_j} = \frac{\delta_g - \delta_\tau \omega_g}{1+\delta_\tau \omega_y}$; $Z_g = \frac{1}{1+\delta_\tau \omega_y}\left[\frac{\delta_g(\delta_y + \delta_\tau \omega_y)}{1-\delta_y} + \delta_\tau \omega_g\right]$; $Z_{du} = \frac{\delta_\tau}{1+\delta_\tau \omega_y}$; $Z_{u_j} = \frac{1}{1+\delta_\tau \omega_y}$; $Z_u = \frac{1}{1-\delta_y} * \frac{\delta_y + \delta_\tau \omega_y}{1+\delta_\tau \omega_y}$; and they are all positive under our parameters' restrictions.[6] 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 shock, u.[7] Looking at the union-wide aggregate demand 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 $\frac{\partial y}{\partial u} = \delta_u(Z_{u_j} + Z_u) = \frac{\delta_u}{1-\delta_y}$.

The before-mentioned elasticities reveal the importance of the interconnections in the union. First, domestic output demand is directly affected by union-wide shocks 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. This paper focuses on asymmetric shocks, defined as $u_j - u$. We can easily see that shock asymmetries 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, e.g., Germany and the rest of the union that both face a positive cost-push shock, inflation in Germany increases, and this leads to a reduction in domestic aggregate demand, but at the same time inflation in the rest of the union increases, which increases Germany's aggregate 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 one of 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, eq. (6); but the monetary authority is not concerned about those shocks, following its loss function, eq. (5), and the union-wide descriptive equations (3) and (4); hence it won't 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 aggregate demand equations, (3) and (8), respectively, we can get the relative output gap, as:

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

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 shock 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 aggregate demand 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

[5] This means that the core/periphery set-up can only be considered in the two leadership strategic regimes, creating a three-stage game. For alternative specifications in a two-country model, see Hughes Hallett and Mavrodimitrakis (2019).

[6] 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 if the fiscal stance is a demand-side policy instrument.

[7] Recall that expected inflation is equal to zero; namely, $\pi^e = 0$.

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, eq. (5), subject to the union-wide descriptive equations (3) and (4). Each national fiscal authority controls its fiscal stance, g_j; under narrow coordination, they minimise their loss function, eq. (6), while under broad coordination they minimise their joint loss function given by equation (7); both subject to the country-specific aggregate demand equation (8). In the core/periphery set-up, the lead (core) fiscal authority takes also into account the peripheral authority's minimisation programme. Each authority's optimisation programme ends up with a corresponding policy rule that combines the concerned macroeconomic variables.

3.1 The Monetary Authority

The Monetary Rule, MR, emerges as:

$$MR: y = -\phi_\pi \pi \tag{10}$$

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 aggregate demand, 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.[8] 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.[9] It can be shown that $sign\left\{\frac{\partial \phi_\pi}{\partial V_g^{ML}}\right\} = -sign\{\delta_g \omega_i + \delta_r \omega_g\}$. Following Chortareas and Mavrodimitrakis (2021), $\delta_g \omega_i + \delta_r \omega_g$ defines relative policy effectiveness; and being indifferent to zero implies that the two policy instruments are not perfect substitutes in the stabilisation process.[10] 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, eq. (10), in the union-wide PC relation, eq. (4), and substituting for the union-wide output gap, y, from the union-wide aggregate demand 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 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 their objectives, since the nominal interest rate becomes a supply-side policy instrument.[11]

[8] Monetary leadership is recently considered by Canofari, Di Bartolomeo, and Messori (2021) to capture active monetary policies towards a financial-stability objective. See also Canofari, Di Bartolomeo, and Messori (2022).

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

[10] Details can be found in the Appendix.

[11] The presence of the cost channel of monetary policy provides an alternative interpretation of the price puzzle; i.e., the observation that a contractionary monetary policy shock is followed by a rise in the price level (Walsh 2017). The cost channel of monetary policy has been empirically observed, but a price puzzle cannot be detected; implying that the nominal interest rate remains a demand-side policy instrument (see, e.g., Gaiotti and Secchi (2006), Chowdhury, Hoffmann, and Schabert (2006) and Henzel et al. (2009)). In our model, this implies $\omega_y \delta_r - \omega_i > 0$.

3.2 The National Fiscal Authorities - The Alternative Fiscal Regimes

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

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

where $\phi_{g_j} = \alpha_F \big[Z_{g_j} + q_j (Z_g - Z_i V_i^{SM}) \big]$ 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 $g = -\alpha_F \sum_{j=1}^{n} \frac{dy_j}{dg_j} q_j y_j = -\alpha_F \Big[Z_{g_j} y + (Z_g - Z_i V_i^{SM}) \sum_{j=1}^{n} q_j^2 y_j \Big]$. It is clear that country-size asymmetry matters as long as there are strategically significant (direct and/or indirect) spill-over effects in the monetary union (Kempf and Von Thadden 2013), defined as $Z_g - Z_i V_i^{SM} \neq 0$; i.e., under interconnections ($Z_g \neq 0$) and/or in the fiscal leadership strategic regime (V_i^{SM} does not vanish).[12] 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:

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

where $k \neq j$ defines another (foreign) country. Now, the national fiscal authorities react to possible changes to foreign output gap, too (so, to the union-wide output gap), as long as there are strategically significant spill-over effects, since $\frac{dy_k}{dg_j} = q_j (Z_g - Z_i V_i^{SM})$. 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, and the union-wide Fiscal Rule, FR, is of the form:

$$FR : g = -\phi_g y \tag{14}$$

where ϕ_g defines the union-wide fiscal reaction parameter. Specifically, summing up equation (13) for all member-states, we get: $g = -\alpha_F (Z_{g_j} + Z_g - Z_i V_i^{SM}) y$; where $\phi_{g_{bc}} = \alpha_F (Z_{g_j} + Z_g - Z_i V_i^{SM}) = \alpha_F \frac{\delta_g - \delta_r V_i^{SM}}{1 - \delta_y}$ and bc stands for broad coordination; and again V_i^{SM} vanishes under either simultaneous move or monetary leadership. Like before, relative output gaps can be computed as:

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

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' reaction to their choice of their fiscal stance; i.e., $\frac{\partial g}{\partial g_j}$ is now replaced by $\frac{dg}{dg_l}$, where $\frac{dy_j}{dg_j} \neq \frac{\partial g}{\partial g_j}$ and the subscript l refers to the lead fiscal authority. The leader's first order condition reads for:

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

where the leader's fiscal reaction parameter is given by $\phi_{g_l} = \tilde{\phi}_{g_l} - \alpha_F^2 (Z_g - Z_i V_i^{SM})^2 q_l \Big[(1 - q_l) Z_{g_j} + (Z_g - Z_i V_i^{SM}) \sum_{k=1, k \neq l}^{n} q_k^2 \Big]$, and $\tilde{\phi}_{g_l} = \alpha_F \big[Z_{g_j} + q_l (Z_g - Z_i V_i^{SM}) \big]$ is the corresponding one if they 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 their fiscal authority follows a less counter-cyclical fiscal policy than the one it would have

[12] 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, $Z_g = Z_i V_i^{SM}$.

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 ($\frac{\partial(|\phi_{g_l}-\phi_{g_l}|)}{\partial\delta_y} > 0$).[13] 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. 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, and this exactly follows the solution in the narrow coordination fiscal regime.[14] 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), $\phi_{g_j}=\phi_{g_{nc}}=\alpha_F\big[Z_{g_j}+\frac{1}{n}(Z_g-Z_iV_i^{SM})\big]$, where nc reads for narrow 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.[15] 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 shock asymmetries; hence the monetary authority reacts only to union-wide shocks, while the burden of stabilising asymmetric shocks lies entirely on the national fiscal authorities (Chortareas and Mavrodimitrakis 2021). Country-size asymmetry plays no role in the stabilisation of shocks in a monetary union in the broad coordination fiscal regime; or in the absence of strategically significant spill-over effects.[16]

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 eq. (16), is given by $\phi_{g_l}=\phi_{g_{nc}}\Big[1-\frac{n-1}{n^2}\alpha_F(Z_g-Z_iV_i^{SM})^2\Big]$; in which $\phi_{g_{nc}}$ is the peripheral fiscal authorities' reaction parameter. Then, the union-wide fiscal rule can be computed as:

$$g=-\phi_{g_{nc}}\Big[y-\frac{n-1}{n^2}\alpha_F(Z_g-Z_iV_i^{SM})^2y_l\Big]=-\phi_{g_{nc}}y+\frac{\phi_{g_{nc}}-\phi_{g_l}}{\phi_{g_{nc}}}y_l \tag{17}$$

where $\frac{\phi_{g_{nc}}-\phi_{g_l}}{\phi_{g_{nc}}}=\frac{n-1}{n^2}\alpha_F(Z_g-Z_iV_i^{SM})^2$. 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 aggregate demand 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:

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

Equation (18),[17] 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 union-wide shocks; so, asymmetric shocks are fully offset at the union level. Moreover, the cost-channel effect ($\omega_i\neq 0$) makes (union-wide) shocks with demand-side effects ($\delta_u\neq 0$) not to be fully offset at the union level, since, following equation (11), V_u is a function of δ_u. In

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

[14] Both equations are shown in the Appendix.

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

[16] In this latter case, moreover, the union-wide equilibrium solutions are the same across the fiscal regimes. This limiting case is presented in the Appendix.

[17] Two points are worth mentioning: (i) in the monetary leadership strategic regime, the monetary reaction parameter, ϕ_π, is a function of $V_{g_{c/p}}^{ML}=V_{g_{nc}}^{ML}(1-\frac{n-1}{n^2}\alpha_FZ_g^2)$, 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 $\phi_\pi^{ML}\neq\phi_\pi^{SM}$.

the absence of the cost-channel effect ($\omega_i = 0$), only shocks with supply-side effects ($\omega_u \neq 0$) affect inflation at the union level (Chortareas and 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 $\omega_g + \omega_i V_i \neq 0$; but $\omega_g + \omega_i V_i = \frac{(\delta_g\omega_i+\delta_r\omega_g)\frac{1}{1-\delta_y}(\frac{1}{\phi_\pi}+\omega_y)}{\frac{\delta_r}{1-\delta_y}(\frac{1}{\phi_\pi}+\omega_y)-\omega_i}$, 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 $\delta_g\omega_i + \delta_r\omega_g \neq 0$. 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:

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

where $\Omega = \delta_r + [\delta_r\omega_y - (1-\delta_y)\omega_i]\phi_\pi - (\delta_g\omega_i + \delta_r\omega_g)\big(\phi_g\phi_\pi + \phi_{g_{nc}} - \phi_{g_l}\big)$.[18] Firstly, 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.

Secondly, 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 ($\delta_g\omega_i + \delta_r\omega_g \neq 0$).[19] 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:

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

Equation (20)[20] shows that the union-wide fiscal stance is also affected by asymmetric shocks at equilibrium, but this is independent on relative policy effectiveness; i.e., it also holds under perfect instrument substitutability (Hughes Hallett and 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 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.[21] The monetary authority will also share the burden of stabilising those shocks with the national fiscal authorities.[22]

Finally, relative output gaps in the narrow coordination fiscal regime and for the lead fiscal authority in the core/periphery set-up are equal, given by:

$$y_j - y = \frac{1}{1 + Z_{g_j}\phi_{g_{nc}}}(Z_{u_j}\delta_u - Z_{du}\omega_u)(u_j - u) \tag{21}$$

where in the core/periphery set-up we simply replace j in both y and u with l. The lead fiscal authority's relative position remains unaltered, but they economise on their policy instrument; and leaves the central bank worse off. The

[18] We call Ω the *reference parameter*, since it 'refers' to a specific institutional arrangement; hence capturing differences on 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). Please see the Appendix. Tables 1 and 2 in the Appendix present the reaction and reference parameters in all the alternative strategic and fiscal regimes; hence providing the equilibrium solutions.

[19] 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 at the first place; namely, $Z_{u_j}\delta_u - Z_{du}\omega_u \neq 0$.

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

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

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

member-states in the monetary union share the stabilisation burden, with a larger monetary union widening the gap, while monetary policy matters only in the fiscal leadership strategic regime.[23]

5 Conclusion

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 shock 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, the implied asymmetric fiscal reactions give rise to a non-neutral union-wide fiscal stance, inducing a monetary reaction. If the two policy instrument are not perfect substitutes in the stabilisation process, then the monetary authority cannot fully offset these asymmetric fiscal reactions, and shock asymmetries pass through at the union level to the inflation rate and the output gap. 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, and provides (closed-form) analytical solutions at equilibrium, in an otherwise (excluding fiscal sequential asymmetries) symmetric monetary union. In a strategic context, this results from the combination of strategically significant spill-over effects, fiscal sequential asymmetries, and imperfect instrument substitutability.

Focusing on the monetary authority, its 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. As a second best, we might think of circumstances where the impact of the core/periphery set-up is reduced; specifically, (i) when the impact of strategically significant spill-over effects is reduced, and (ii) when the degree of substitutability of the two policy instruments is higher. The former can be induced by the fiscal leadership strategic regime, especially when the direct spill-over effects (namely, the interconnections) are non-trivial, since this weakens the asymmetric fiscal reactions, providing a form of implicit coordination among the authorities (Hughes Hallett and Weymark 2007), while the latter by inducing fiscal authorities to use policy instruments that directly affect inflation negatively, like taxes and/or production subsidies, or public investment, especially under 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. Finally, it might be also interesting to explore a regime of cooperation between the monetary authority and the lead fiscal authority in the union, probably with the rest of the union as the follower. Although Hughes Hallett and Mavrodimitrakis (2019) have shown that this is the worst institutional arrangement (among others) for the monetary authority, exactly because asymmetric shocks can pass through at the union level, the authors do not consider policies' supply-side effects, so the two policy instruments are perfect substitutes in the stabilisation process. Under imperfect instrument substitutability, however, where asymmetric shocks pass through by default, as we have shown in this paper, a possible cooperation might be welfare-enhancing, even for the peripheral member-states (although this is not the case in Hughes Hallett and Mavrodimitrakis (2019)). Of course such an institutional arrangement jeopardises central bank's independence; and thinking of the EMU, this is clearly prohibited by the European Central Bank's (ECB) mandate.

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

6 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

[23] In the broad coordination fiscal regime, equation (15) can be obtained after replacing $\phi_{g_{nc}}$ with $\alpha_F Z_{g_j}$ in equation (21).

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; i.e., 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 $\delta_g\omega_i + \delta_r\omega_g = 0$.

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 equations (12) and $g = -\alpha_F\Big[Z_{g_j}y + (Z_g - Z_iV_i^{SM})\sum_{j=1}^n q_j^2y_j\Big]$, and using equation (9), we get:

$$y_j - y = \frac{1}{1+\alpha_F Z_{g_j}^2}\Big[-\alpha_F Z_{g_j}(Z_g - Z_iV_i^{SM})(q_jy_j - \sum_{j=1}^n q_j^2y_j) + (Z_{u_j}\delta_u - Z_{du}\omega_u)(u_j - u)\Big] \tag{A.1}$$

This exactly holds in the core/periphery fiscal regime, too, replacing j with l in the subscripts of y, q and u; but $\sum_{j=1}^n q_j^2y_j$ remains.

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:

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

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

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 affects the monetary reaction parameter, following eq. (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: $V_{g_{nc}}^{ML} = \frac{\alpha_F\delta_r}{1-\delta_y}(Z_{g_j} + Z_g\sum_{j=1}^n q_j^2)$; $V_{g_{bc}}^{ML} = \frac{\alpha_F\delta_g\delta_r}{(1-\delta_y)^2}$; and $V_{g_{c/p}}^{ML} = \frac{\alpha_F\delta_r}{1-\delta_y}\Big\{Z_{g_j} + Z_g\sum_{j=1}^n q_j^2 - \alpha_F Z_g^2q_l\big[(1-q_l)Z_{g_j} + Z_g\sum_{k=1,k\neq l}^n q_k^2\big]\Big\}$. 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 $V_{g_{c/p}}^{ML} = Z_i\phi_{g_l}^{ML}$. 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 imperfect substitutes, since $sign\Big\{\frac{\partial\phi_\pi}{\partial V_g^{ML}}\Big\} = -sign\{\delta_g\omega_i + \delta_r\omega_g\}$.

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 equation, (9), we compute equilibrium relative output gaps, as:

$$y_j - y = \frac{1}{1+\alpha_F\delta_g^2}\delta_u(u_j - u) \tag{A.3}$$

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, eq. (19), with the monetary rule, eq. (10), we can obtain the output gap, as:

$$y = -\frac{\phi_\pi}{\Omega}\left[(\omega_i\delta_u + \delta_r\omega_u)u + \frac{(\phi_{g_{nc}} - \phi_{g_l})(\delta_g\omega_i + \delta_r\omega_g)}{1 + Z_{g_j}\phi_{g_{nc}}}(Z_{u_j}\delta_u - Z_{du}\omega_u)(u_l - u)\right] \tag{A.4}$$

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

$$i = \frac{1}{\Omega}\left\{\big[\phi_{g_l}\phi_\pi V_i(\omega_i\delta_u + \delta_r\omega_u) + V_u\Omega\big]u + (\phi_{g_{nc}} - \phi_{g_l})\frac{\delta_r + [\delta_r\omega_y - (1-\delta_y)\omega_i]\phi_\pi}{1 + Z_{g_j}\phi_{g_{nc}}}V_i(Z_{u_j}\delta_u - Z_{du}\omega_u)(u_l - u)\right\} \tag{A.5}$$

Tables 1 and 2, below, 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 (A.4) - (A.5).

Regimes		Reaction Parameters	
Strategic	Fiscal	$\boldsymbol{\phi_\pi}$	$\boldsymbol{\phi_g}$
SM	NC	$\frac{1}{\alpha_M}\left(\omega_y - \frac{\omega_i}{Z_i}\right)$	$\alpha_F\left(Z_{g_j} + \frac{1}{n}Z_g\right)$
	BC		$\frac{\alpha_F \delta_g}{1-\delta_y}$
FL	NC		$\alpha_F\left[Z_{g_j} + \frac{1}{n}\left(Z_g - Z_i V_i^{SM}\right)\right]$
	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	$\frac{1}{\alpha_M}\left[\omega_y + \left(1-\delta_y\right)\frac{\omega_g Z_i \phi_{g_l}^{ML} + \omega_i}{\delta_g Z_i \phi_{g_l}^{ML} - \delta_r}\right]$	$\phi_g = \phi_{g_{nc}}^{ML}; \phi_{g_l} = \phi_{g_{nc}}^{ML}\left(1 - \alpha_F \frac{n-1}{n^2} Z_g^2\right)$

Table 1: The Reaction Parameters under the Alternative Strategic and Fiscal Regimes

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

Table 2: The Reference Parameter under the Alternative Strategic and Fiscal Regimes

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