INSTITUTE
OF ECONOMICS

Scuola Superiore
Sant'Anna

LEM | Laboratory of Economics and Management

Institute of Economics
Scuola Superiore Sant'Anna

Piazza Martiri della Libertà, 33 - 56127 Pisa, Italy
ph. +39 050 88.33.43
institute.economics@sssup.it

LEM
WORKING PAPER SERIES

Fiscal Transfers and Common Debt in a Monetary Union: A Multi-Country Agent Based-Stock Flow Consistent Model

Alessandro Caiani [a]
Ermanno Catullo [b]

[a] University School of Advanced Studies (IUSS), Pavia, Italy.
[b] University of Teramo, Italy.

2023/19 **May 2023**
ISSN(ONLINE) 2284-0400

Fiscal Transfers and Common Debt in a Monetary Union: A Multi-Country Agent Based-Stock Flow Consistent Model

Alessandro Caiani*
University School of Advanced Studies (IUSS) Pavia

Ermanno Catullo
University of Teramo

Abstract

Using a refined version of the multi-country AB-SFC model of a Monetary Union already presented in Caiani et al. (2018a, 2019) the paper aims at providing a tentative assessment of the economic effects of transforming the European Monetary Union into an Intergovernmental Fiscal Transfer Union (IFTU) with its own fiscal capacity. Countries contribute proportionally to their GDP whereas funds are redistributed according to a mechanism that gives more funds to countries performing worse than the average of the Union in cyclical terms. Our simulations show that an IFTU inspired by such a redistribution principle acts as a stabilizer of international trade, allowing to stabilize and improve the Union GDP performance without affecting the stability of public finances. When the Union is allowed to borrow on capital markets, i.e. in a Fully-Fledged Fiscal Transfer Union (FFFTU), these effects are enhanced and a part of the public debt burden shifts from the national to the Union level, leaving the total burden almost stable. An interesting result to assess the political acceptability of the proposal is that 'core' countries eventually benefit the most from the introduction of this mechanism, despite being more frequently net contributors. Finally, we show that an FFFTU with common debt might help to soften the impact of an exogenous demand shock while, because of the fact that it mainly operates as a stabilizer of aggregate demand, it does not seem to provide beneficial effects when facing a supply shock to production.

Keywords: Fiscal Transfer Union, Union Bonds, European Integration, Agent Based Macroeconomics, Stock Flow Consistent Models.
JEL Codes: F45, F41, C63

1 Introduction

In recent years, the Euro Debt Crisis, first, and more recently, the Covid-19 pandemic, have given a new impetus to the discussion on how to complete the Economic and Monetary Union (EMU) and increase its economic resilience. As pointed out by Monnet (1978), each crisis indeed exerts a fundamental influence on the direction of the European integration process, forcing the hand of reluctant policy actors. The Euro Debt Crisis marked a significant turning point for monetary policy, characterized by a far more active role played by the European Central Bank, inspired by a broadened interpretation of its mandate. The reform of the European fiscal rules

*Corresponding author: alessandro.caiani@iusspavia.it

and the process of fiscal integration have lagged behind until the outbreak of the Covid-19 crisis, which led to an unprecedented response by the European institutions. While the prompt launch of the massive pandemic emergency purchase program (PEPP) by the ECB[1] already marked a striking difference with the inertia affecting the ECB's intervention in the aftermath of the Euro Crisis, the discontinuity with the past was even more striking on the fiscal side.

In May 2020, the European Union agreed to suspend, for the first time, the stringent fiscal provisions of the Stability and Growth Pact (SGP) to give to those countries most hit by the coronavirus more fiscal space to counteract the recession, regardless their level of indebtedness.[2] During the same month, the governments of France and Germany proposed a 500 billion Recovery Fund that paved the way for an agreement on the Next Generation EU (NGEU) Program by the European Council in July 2020. The program was geared around the Recovery and Resilience Facility, a 750 billion fund with 390 billion to be distributed in grants and 360 in loans, aiming to fund reforms and investments in Member States up to the end of 2026. Besides the magnitude of the fiscal stimulus, the main novelty brought by the Franco-German original proposal and by the NGEU program lay in that they both broke two long-lasting European fiscal taboos. First, they legitimized the principle of fiscal transfers within the Union and the need to complement the rules designed to promote countries' fiscal discipline with a distinct redistributive dimension. Secondly, the deal called for the European Commission to borrow on the capital markets on behalf of the entire EU, thus opening the way to the issuance of common debt.

The symmetric and exogenous nature of the Covid-19 crisis undoubtedly played a significant role in garnering political support for the proposal, particularly among countries that had traditionally been hesitant or even hostile towards the idea of a fiscal transfer union with shared debt. However, while the agreement is recognized as exceptional and temporary, it has the potential to serve as a significant step towards greater European integration by transforming the European Monetary Union into a fully-fledged Fiscal Transfer Union with its own fiscal capacity. In fact, exceptional policy measures introduced as temporary tools to face an emergency often become difficult to reverse later on (D'Erman and Verdun, 2018; Ladi and Tsarouhas, 2020).

The paper aims to provide a tentative assessment of the economic effects of transforming the European Monetary Union into an Intergovernmental Fiscal Transfer Union (IFTU) with its own fiscal capacity, partly funded by national contributions by member countries and partly by the issuance of common debt. We refer to an IFTU as a system in which national governments agree to share financial resources to address economic imbalances and promote stability, involving the transfer of funds from stronger member states to weaker ones, with the goal of supporting economic growth and stability across the Union. More precisely, we propose a mechanism of redistribution where each country contributes to a Union budget proportionally to its GDP and receives a share that is inversely related to the difference between its cyclical growth and the Union average.

Our analysis is carried out using the multi-country AB-SFC model of a Monetary Union presented in Caiani et al. (2018a, 2019). The model has been shown to yield reasonable values for the dynamics and relative dimension of key variables, broadly comparable with historical data

[1] Already in March, the ECB announced the pandemic emergency purchase program (PEPP), a temporary asset purchase program of private and public sector securities aimed at countering the threats to the monetary policy transmission mechanism and to financial stability posed by the pandemic. Originally worth 750 billion euros, the program was later increased by 600 billion in June and 500 billion in December. Cumulative net purchases under the PEPP as of June 2022 were at 1719 billion, and the reinvestment of maturing principal payments is expected to last until the end of 2024.

[2] Discussions about a possible reactivation of the rules in 2023 has been instantaneously cast aside after the Russian invasion of Ukraine and, since the outbreak of the Covid-19 crisis, there has been growing consensus on the need for a broad reform of European fiscal rules aimed at softening the excessive rigidities of the past (European Commission, 2022).

and available stylized facts for the European Monetary Union (Caiani et al., 2018a). Caiani et al. (2018a) investigated the effect of changes to the deficit-to-GDP threshold imposed on member countries by a Stability and Growth Pact-like legislation and how the dimension of the common market influences the results. Caiani et al. (2019) instead examined the impact of alternative wage growth patterns on the economic dynamics of the Monetary Union, differentiating between changes occurring in a single country and coordinated changes that occur simultaneously across all countries. In this work, the model framework has been integrated by adding two novel institutional architectures: an IFTU funded by national contributions only, and a fully-fledged Fiscal Transfer Union (FFFTU) which foresees the possibility of issuing common debt instruments.

Results show that the IFTU and, even more, the FFFTU enhance the stability and performance of the Union GDP, without causing an increase in the overall debt burden. This result is mainly achieved through the stabilizing effect on international trade exerted by the redistribution rule. Providing support to the demand of countries with a worse cyclical performance, this rule in fact indirectly stabilizes their demand for the exports of other countries. This way, a critical contagion channel through trade is softened. Our simulations also show that high-productivity, high-income 'core' countries tends to benefit more from the introduction of an FFFTU thanks to their higher competitiveness in the internationally integrated market for tradables. This translates into a better dynamics of their external balance, eventually resulting into an improvement of their public debt-to-GDP ratios. This improvement makes core countries more likely to be net contributors to the Union budget which in turn allows to improve in a balanced way the GDP growth also in the periphery. This result seems to be critical to evaluate the political acceptability of an FFFTU, reversing the argument that the benefits of a fiscal transfer union would primarily accrue to the countries receiving transfers, while the costs would be spread among the wealthier ones. Instead, our result suggests that being net contributors might be the consequence of the bigger benefits accrued by core countries. Finally, we tested the efficacy of the IFTU and FFFTU in tackling the consequences of exogenous and symmetric demand and supply shocks. Results suggests that an FFFTU seems to provide some beneficial effects when facing a demand shock, reducing the amplitude of the recession and the cumulative loss of GDP over time. Conversely, a Fiscal Transfer Union does not seem to bring significant advantages when faced with a shock to production. This result comes to no surprise given that the fiscal transfer union mainly operates as a stabilizer of aggregate demand.

The rest of this paper is organized as follows: Section 2 reviews the relevant literature, Section 3 presents the model and the integrations made to include the IFTU and FFFTU institutional schemes. Section 4 presents the results of our experiments and discusses their underlying mechanisms and their policy relevance. Section 5 concludes. Appendices A and B provide additional details on the baseline calibration and discuss the results of a robustness check with varying numbers of countries.

2 Literature review

First and foremost, this paper contributes to the literature on Fiscal Transfer Unions, a topic that has long been studied within the literature dealing with Optimal Currency Areas (OCAs) (Mundell, 1961). In particular, Kenen (1969) has emphasized the importance of fiscal integration, that is, a large federal component of spending at the regional or local level, for the success of an OCA when dealing with asymmetric shocks. In recent years, the European sovereign debt crisis reignited the debate on the extent and type of fiscal integration that the European Union should aim to achieve. While the economic consensus at the dawn of the European Monetary Union was mainly concerned with the risk that international risk sharing schemes could weaken

the fiscal discipline of member countries (Beetsma and Bovenberg, 2001), the historical events of the subsequent two decades have led to a revival of interest in the effects of activist fiscal policies (Auerbach et al., 2010; Constâncio, 2020) and shifted the attention to the potential benefits, in terms of stabilization and convergence, of a Fiscal Union characterized by a significant degree of risk sharing and by cross-country fiscal transfers (Berger et al., 2019). Arnold et al. (2018), for example, make a concrete proposals for building a euro area central fiscal capacity to help smooth both country-specific and common shocks.

The political acceptability of a Fiscal Transfer Union in relation to the European integration process has also been explored thoroughly within the political science literature. These contributions have focused in particular on explaining the reasons for the reticent fiscal stance by 'core'-northern countries, in particular by Germany (Howarth and Schild, 2021), and the reasons explaining the major shift in their preferences observed in the face of the Coronavirus pandemic towards a grants-based EU recovery fund that apparently broke a long-lasting 'budgetary taboo' (Crespy and Schramm, 2021).

By contrast, despite the renewed interest in European fiscal integration, the macroeconomic modeling literature has yet to catch up. In the DSGE literature, for example, it has been noted by Farhi and Werning (2017) that, despite the increasing attention to exploring the optimal use of macroeconomic instruments beyond monetary policy, there has been almost no consideration of the case of fiscal transfers across union members. The authors resurrect the argument proposed by Kenen (1969) that fiscal unions represent an optimal risk-sharing arrangement within a currency union and introduce an open economy New Keynesian model to explore the concept of cross-country risk-sharing through international transfers between countries sharing a currency. Their analysis highlights the dual role of international transfers: first, they facilitate the smoothing of consumption across countries, and secondly, transfers from booming countries to struggling ones enhance macroeconomic stability within the currency union. However, private economic agents only internalize the smoothing effect of international transfers on consumption, while they fail to acknowledge the indirect macroeconomic stability effects. This leads to sub-optimal levels of international risk-sharing even when ideal conditions of complete financial markets are met, indicating the need for government intervention. To the best of our knowledge, only two other works in the new Open Economy DSGE literature have explored a similar fiscal instrument. Bandeira (2018) investigates a fiscal transfer scheme in a two-country monetary union framework that operates when sovereign spreads widen. The study demonstrates how such a scheme can ease the strain on fiscal policy and mitigate the transmission of sovereign risk to private lending to firms. Economides et al. (2016) analyzes a monetary union with fiscal transfers using a medium-scale DSGE model that consists of two heterogeneous countries (calibrated on Germany and Italy). The study examines welfare changes under various transfer scenarios and finds that fiscal transfers as insurance have no effect on welfare. However, fiscal transfers as redistribution have significant implications, depending on whether they trigger moral hazard behaviors.

Similarly, the topic of Fiscal Union has received limited investigation within the emerging Agent-Based and Stock-Flow Consistent macroeconomic modeling literature, which represents another fundamental strand to which the paper aims to contribute. Over the past decade, much of the literature in this area has been dedicated to exploring the impact of various fiscal policies, with an emphasis on disentangling their interplay with monetary policy, financial fragility, and trade imbalances (see, among the others, Godley and Lavoie (2007); Caiani et al. (2018a); Zezza (2012); Dosi et al. (2013, 2015)), particularly in relation to the European context.

However, to the best of our knowledge, within the macro ABM literature, only Dawid et al. (2018b) explicitly considers fiscal transfers and some degree of sharing of the debt burden across member countries, although this latter takes the form of a rule to share interest and principal repayments on national debts rather than the actual issuance of common debt instruments at

the Union level. The authors build upon the two-country extension of the Eurace@Unibi model (Deissenberg et al., 2008) presented in Dawid et al. (2012a, 2014) and show that sharing the debt burden of the periphery has almost no effect on the growth dynamics of that region, whereas fiscal transfers have a positive impact on per-capita consumption that is enhanced when these union funds are provided in the form of technology-oriented subsidies to firms in the periphery. Dawid et al. (2018a) deepen this analysis by studying the effects of different types of technology-oriented cohesion policies. While we share with these contributions the interest in fiscal transfers within a monetary union, our work distinguishes itself in several ways. Firstly, we employ a multi-country framework involving more than two regions, contributing to the underdeveloped literature of multi-country macroeconomic Agent-Based models. Existing examples include the LAGOM model for climate policy assessment Wolf et al. (2013), the evolutionary model of an artificial monetary Union proposed by Rengs and Wäckerle (2014), the open version of the Eurace model (Cincotti et al., 2010; Holcombe et al., 2013) presented in Petrovic et al. (2017) and later employed to analyze the opportunity of joining a Monetary Union (though in a simplified two-country setting) in Petrovic et al. (2020), and the multi-country model inspired by the 'Schumpeter+Keynes' family of models Dosi et al. (2017).

Secondly, similarly to (Arnold et al., 2018), we focus on a redistribution scheme that, by focusing on the relative cyclical performance of countries, enhances its stabilization character and prevents permanent transfers across regions characterized by heterogeneous economic conditions. This feature may, in fact, contribute to gaining acceptance from core countries. Another key feature of our analysis with respect to those mentioned before is that it explicitly examines the establishment of an independent fiscal capacity at the union level possibly involving, in the FFFTU institutional configuration, the issuance of shared debt. Conversely, while our model incorporates endogenous technological change through imitation and innovation, following the evolutionary approach (Nelson and Winter, 1977b, 1982) popularized in the Agent-Based literature by Dosi et al. (2010), it does not provide as detailed a characterization of technology as in Dawid et al. (2018b,a). Additionally, we focus on monetary transfers to consumers and do not consider subsidies targeted specifically at firms to support technology-oriented initiatives; thus, our policy scheme mainly operates on the demand side.

Finally, our paper broadly contributes to the emerging Agent-Based macroeconomic literature (Dosi et al., 2010; Ciarli et al., 2010; Dawid et al., 2012b; Gualdi et al., 2015; Assenza et al., 2015, 2018; Riccetti et al., 2015; Russo et al., 2016; Lorentz et al., 2016; Caiani et al., 2016, 2020; S. et al., 2022) that has been extensively reviewed in Dawid and Dell Gatti (2018); Axtell and Farmer (2022) and, with a special focus on the comparison between the treatment of monetary and fiscal policies in Agent-Based and DSGE models, in Fagiolo and Roventini (2016).

3 Model Description

The model depicts an artificial Monetary Union composed of K countries. Each country k is populated by an equal number of households H and by an endogenously varying number of firms (I_{kt}) and banks (Z_{kt}). Firms' and banks' entrance is steered by households' endogenous investment in equity. During the simulation, however, firms and banks can default, thus exiting the market.

In comparison to the previous versions of the model (Caiani et al., 2018a, 2019), the main novelty is represented by the inclusion of a fiscal budget at the Union level which opens the possibility for intergovernmental fiscal transfers.

Figure 1 provides a graphical representation of the structure of each national economy, its trade and financial relationships with other countries of the Union (the correspondent flows being

marked in red), and the connections with the Union Central Bank and Fiscal Budget (with the correspondent flows marked in blue). Firms use only labor to produce their output and are classified into 'tradable' and 'non-tradable' depending on whether they produce goods that are traded on the common market or just on the domestic one. For simplicity reasons, labor cannot move across countries.

Firms invest in R&D in order to achieve innovations that increase the labor productivity of their employees, reducing unit costs of production. Furthermore they are allowed to imitate the technology of their competitors so to catch up with the industry standards. This gives rise to sectoral spillovers.

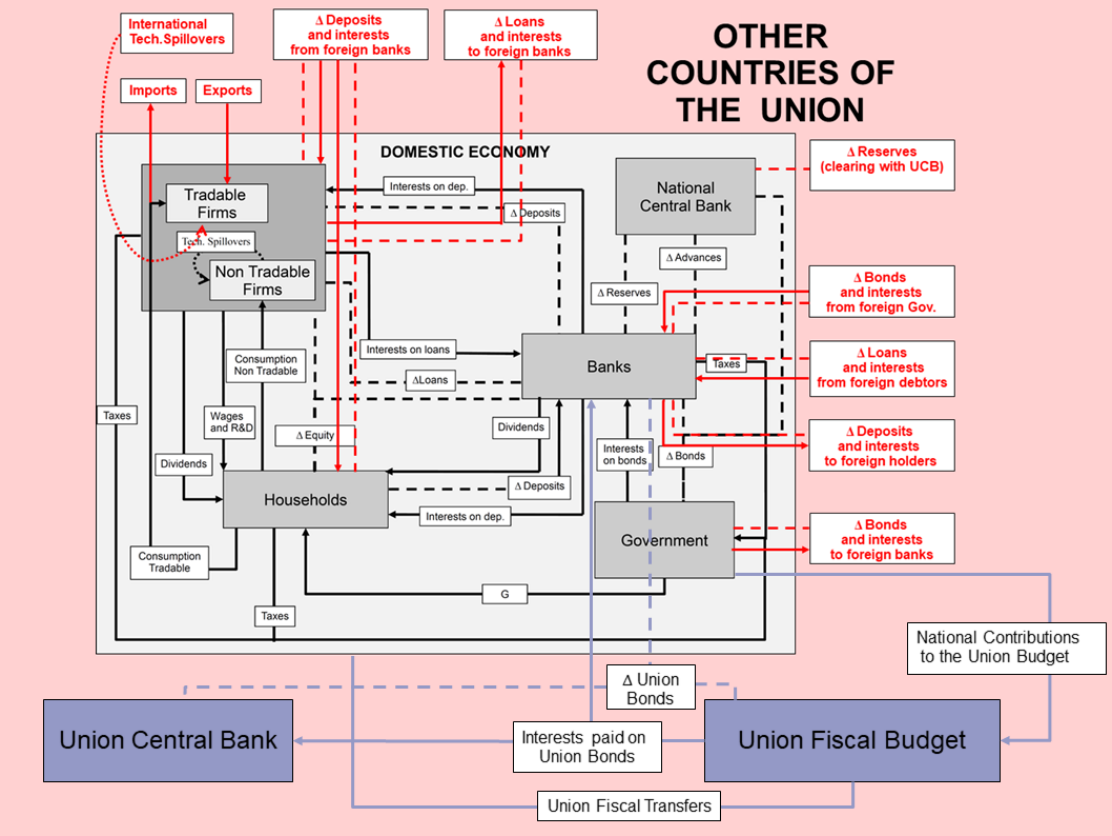

Figure 1: Flow Diagram of a national economy *versus* the rest of the Union. Arrows point from paying sectors to receiving sectors. Dashed lines represent net variations in the quantity of different financial stocks determined by the associated flows originated during the period and connect those who hold them as assets to those who hold them as liabilities: for example, the dashed line labeled as $\Delta Loans$ connecting firms to banks indicates the variation in the stock of credit from the banking sector to productive ones arising from the net balance between the flow of principal repayments on loans granted in the past and the flow of newly-issued ones. Finally, dotted lines are used to graphically represent domestic technological spillovers in the non-tradable sector and national/international technological spillovers in the tradable sector originating from firms' imitation activity.

Transactions (both domestic and international) are cleared through money transfers from the deposit account of the buyers to the deposit account of the sellers and thereby also imply a movement of legal reserves from the bank of the buyers to that of the sellers.

Firms' financing needs can be covered using internal resources or asking credit to banks: firms can apply for loans to both domestic and foreign banks. Instead, households are assumed for simplicity reasons to invest only in the equity of domestic firms and banks.

Governments collect taxes on income and profits and provide public spending in the form of a lump-sum monetary transfer to households. Countries have a maximum deficit-to-GDP ratio that they commit to comply by tuning spending and tax rates. National governments can finance their deficits by issuing bonds on an internationally integrated market that are sold to commercial banks.

The Union is endowed with its own fiscal budget to which national governments contribute proportionally to their GDP by rising a dedicated tax that tops up to taxes on income and profits. This budget is then redistributed to countries - according to different rules depending on the scenario analyzed - in the form of a monetary grant to their households. However, the flow diagram in figure 1 also features the case in which the Union can autonomously determine its own budget and fund the exceeding part over national contributions by issuing Union bonds which are purchased by commercial banks and, for any residual part, directly by the Union Central Bank.

This latter represents the monetary authority and sets the policy rate for banks' main refinancing operations and accommodates their requests through National Central Banks. National Central Banks are also in charge of buying on behalf of the Union Central Bank any amount of bonds issued by their country's government that have not been purchased by private banks.[3]

As in the preceding versions of the model, agents interact in a decentralized way through specific matching protocols on the various markets modeled. Six types of markets are considered: national non-tradable good markets, national labor markets and national deposit markets, a common tradable good market, and common credit and bond markets.

The following sub-sections discuss the behaviors of agents and the rules of their interactions.

3.1 Agents

3.1.1 Households

Households in the models act as workers, equity holders, and consumers.

In their role as workers, households interact with ψ randomly sampled potential employers, trying to earn a salary by selling their labor force l^S, whose quantity is normalized to 1. The worker is considered full-time employed when $l_{h,t}$, the total quantity of labor sold by household h in time t, is equal to 1. They are unemployed when $l_{h,t} = 0$. Finally, $0 < l_{h,t} < 1$ indicates that the worker is part-time employed. This latter condition may occur when an employer needs just a fraction of a worker's labor force, or when a financial constraint prevents them from paying a full salary to the worker. Part-time workers, however, can work for several employers until they eventually exhaust their unitary labor force. The total labor force sold by worker h in period t is then given by: $l_{h,t} = \sum_{i,l_{hi,t}>0}^{I_{k,t}} l_{hi,t}$, where $l_{hi,t}$ represents the quantity sold to each employer i, for which they receive a wage equal to $w_{hi,t}l_{hi,t}$.

Workers rank potential employers according to their offered wage and refuse any job offer below their reservation wage $w_{h,t}$. The reservation wage is adaptively revised from period to

[3]Therefore, while in our simulations we do pay attention to the stability of public finance (as captured by deficit- and debt-GDP ratios) and we also account for the fact that more indebted countries tend to face higher financing costs all other things being equal, the possibility of a sovereign debt crisis where a country is not able to fund its bonds is excluded by design.

period according to equation 1:

$$w_{h,t} = \begin{cases} w_{h,t-1}(1 + U[0,\delta]), & \text{if } l^S - l_{h,t-1} = 0 \text{ with } Pr(w^+_{h,t}) = \upsilon_H e^{-\upsilon u_{t-1}} \\ w_{h,t-1}(1 - U[0,\delta]), & \text{if } l^S - l_{h,t-1} > 0 \text{ with } Pr(w^-_{h,t}) = 1 - \upsilon_H e^{-\upsilon u_{t-1}} \end{cases} \tag{1}$$

The equation suggests that full-time employed workers may consider increasing their reservation wage, while unemployed and part-time workers tend to decrease it. The magnitude of these revisions is given by a random sample from a Uniform distribution ($U[0,\delta]$) defined between 0 and δ. However, these revisions occur in each period with a probability lower than one, depending on the aggregate rate of unemployment. Since workers' wage claims are negatively (positively) affected by higher (lower) levels of unemployment, upward revisions are more likely to occur when unemployment is low, while downward revisions are more likely if unemployment is high.

These probabilities depend on the negative exponential function $\upsilon_H e^{-\upsilon u_{t-1}}$, where $\upsilon > 0$ is a shaping parameter, and υ_H is a scaling parameter. Its value is calibrated in relation to the corresponding scaling parameter υ_F appearing in the revision rule for the offered wage of firms (equation 15 in section 3.1.2) to keep the dynamics of reservation and offered wages broadly in line.[4] This prevents workers' reservation wages from rising too fast compared to firms' offers. In fact, the condition under which firms contemplate the possibility of increasing wages (i.e., having been unable to fill all vacant positions) is typically less frequent than the condition inducing workers to consider raising their reservation wage (i.e., having been full-time employed).

Workers employed in the production process are homogeneous and they are assumed to participate also in R&D activities. Therefore, funds invested by firms in R&D ($R\&D_{i,t}$, see section 3.1.2) top up to workers' labor income, being distributed proportionally to the quantity of labor they individually supply.

In addition to their labor income, households receive interests on deposits $D_{h,t}$ from banks, dividends from firms and banks ($Div_{h,t}$) of which they hold equity, and a tax-exempt monetary transfer ($G_{k,t}/H$) from the government of their country k.

Households' gross and net income, $y_{h,t}$ and $y^D_{h,t}$, respectively, can then be expressed as:

$$y_{h,t} = \sum_{i,l_{hi,t}>0}^{I_{k,t}} w_{hi,t} l_{hi,t} + r_{d,t} D_{h,t} + Div_{h,t} + \sum_{i,l_{hi,t}>0}^{I_{k,t}} R\&D_{i,t} \frac{l_{hit}}{l_{it}} \tag{2}$$

$$y^D_{h,t} = (1 - \tau_{k,t}) y_{h,t} + \frac{G_{k,t}}{H} \tag{3}$$

where $\tau_{k,t}$ is the tax rate charged by the government of the home-country k in period t.

Households' nominal consumption ($C^D_{i,t}$) is a standard linear function of current disposable income and current wealth (i.e. bank deposits plus equity participations in firms and banks), with fixed marginal propensities c_y and c_w:

$$C^D_{h,t} = c_y y^D_{h,t} + c_w (D_{h,t} + A_{h,t}) \tag{4}$$

Consumption is then split between tradables ($C^{DT}_{h,t}$) and non-tradables ($C^{DNT}_{h,t}$) in fixed proportions, c_T and $1 - c_T$ respectively.

[4] Please notice that, according to equation 1, the probability of an upward revision for a full-time worker is defined as the complement to 1 of the probability of a downward revision for an unemployed or part-time worker, and vice versa: $Pr(w^+_{h,t}) = 1 - Pr(w^-_{h,t})$.

$$C_{h,t}^{DT} = c_T C_{h,t}^{D} \tag{5}$$

$$C_{h,t}^{DNT} = (1 - c_T) C_{h,t}^{D} \tag{6}$$

The interaction between consumers and producers in both the tradable and non-tradable markets assumes that consumers sample ψ potential suppliers and rank them according to their overall appeal. This appeal depends on the price and the distance between the variety of goods produced and the consumer's innate preferences. The model employs a circular Hotelling's locational specification (Salop, 1979) for consumers' preferences and firms' offered varieties. This specification assumes that the varieties of goods produced by different firms and the preferences of different consumers can be represented on a circle with a unitary diameter. We indicate by d_{hi} the distance between a consumer h's preferences and a firm i's offered variety.[5]

Consumers rank potential suppliers according to the following rule, for which an household h prefers firm i to firm j if:

$$\frac{1}{d_{hi}^{\beta}} \frac{P_t}{p_{i,t}} > \frac{1}{d_{hj}^{\beta}} \frac{P_t}{p_{j,t}} \tag{7}$$

where $p_{i,t}$ and $p_{j,t}$ are the prices charged firms i and j, P_t is the sector average price. The exponent $\beta \geq 0$ is a parameter that reflects households' preferences for variety. When β is lower, consumers place less emphasis on d_{hi} and become more sensitive to price differences.

Consumers aim to purchase goods from higher-ranked firms but will turn to lower-rated suppliers if they cannot fulfill their demand.

Households keep their financial wealth in two forms: checking accounts at commercial banks $D_{h,t}$ that earn a positive interest rate $r_{d,t}$ and participations in the equity of firms and banks $A_{h,t}$, which yield dividends when profits are positive. The allocation of new savings between these two types of financial assets is determined by comparing the return on past equity investments $\frac{Div_{h,t-1}}{A_{h,t-1}}$, adjusted for expected risk as measured by the extinction rate of firms and banks $Pr^{default}t$, with the interest accrued on households' checking accounts rd, t, which is considered a risk-free asset.[6] This comparison determines households' preference for liquid assets $lp_{h,t}$, which represents the target share of wealth that households wish to hold in the form of bank deposits. The complement is the share that households would like to keep in the form of equity.[7]

$$lp_{h,t} = \begin{cases} \lambda e^{-(\frac{Div_{h,t-1}}{A_{h,t-1}}(1-Pr_t^{default})-r_{d,t})} & \text{if } \frac{Div_{h,t-1}}{A_{h,t-1}} \geq r_{d,t} \text{ and } A_{h,t-1} \geq 0 \\ \lambda & \text{if } \frac{Div_{h,t-1}}{A_{h,t-1}} < r_{d,t} \text{ or } A_{h,t-1} = 0 \end{cases} \tag{8}$$

In order to ensure a minimum level of investment in every period, the parameter λ acts as an exogenous upper (lower) threshold for the share of wealth that households want to hold in the form of deposits (equity).

Therefore, indicating by $NW_{h,t}^{D} = NW_{h,t-1} + y_{h,t}^{D} - C_{h,t}^{D}$ households' expected level of net worth based on their net income and their planned consumption, we can derive the desired levels

[5] Formally, $d_{hi} = sin(min[|\omega_h - \omega_i|, 2\pi - (|\omega_h - \omega_i|)]/2)$, where ω_i is the radian value that uniquely identifies the position of firm i, and ω_h is the analogous value that identifies consumer h's preferences.

[6] For simplicity, we assume that every bank offers the same interest rate $r_{d,t}$, and households choose among them randomly.

[7] For simplicity, we define the extinction rate as a weighted average of the extinction rates of firms and banks: $Pr^{default}t = \frac{I^{default}t-1+Z^{default}t-1}{It-1+Z_{t-1}}$, where $I^{default}t$ and $Z^{default}t$ are respectively the number of firms and banks that default in period t.

of equity and deposits as:

$$A^D_{h,t} = max\left\{A_{h,t-1}, (1 - lp_{h,t})NW^D_{h,t}\right\} \tag{9}$$

$$D^D_{h,t} = NW^D_{h,t} - (A^D_{h,t} - A_{h,t-1}) \tag{10}$$

where $A^D_{h,t} - A_{h,t-1}$ is the desired investment in equity, which is bound to be non-negative.[8] If actual consumption ($C_{i,t}$) is lower than desired, e.g. due to the presence of some supply constraint, deposits are assumed to act as buffer stock, ending up being higher than originally planned, whereas investment in equity sticks to its planned level.

Funds devoted to equity investments by households are then hoarded into a joint investment fund to create a new firm or a new bank. When funds collected are above the threshold, households allocate the funds originally intended for equity investment to their bank accounts, which, in this circumstance, also act as a buffer. Please note that, when a large quantity of funds is collected, more than one firm (bank) can possibly enter the market.

3.1.2 Firms

Firms determine the quantity of output that they desire to produce $q^D_{i,t}$ based on their expectations about sales $q^e i, t$, and having a target level of inventories expressed as a share θ of expected sales, that they want to hold as a buffer against unexpected demand swings and production bottlenecks (Steindl, 1952; Lavoie, 1992). Indicating by $invi, t$ the stock of inventories inherited from previous periods at time t, the desired production is thus:

$$q^D_{i,t} = q^e_{i,t}(1 + \theta) - inv_{i,t} \tag{11}$$

Prices $p_{i,t}$ and real sales expectations $q^e_{i,t}$ of firm i are revised adaptively from period to period according to a simple scheme which looks at previous-period production $q_{i,t-1}$, previous-period sales $\hat{q}_{i,t-1}$, and the total amount of goods available for sales in $t-1$, that is, $q^{tot}_{i,t-1} = q_{i,t-1} + inv_{i,t-1}$.

$$if\ \hat{q}_{i,t-1} \geq \hat{q}^e_{i,t-1} : \begin{cases} \hat{q}^e_{i,t} = \hat{q}^e_{i,t}(1 + U[0, \delta]) \\ p_{i,t} = p_{i,t-1}(1 + U[0, \delta]) \end{cases} \tag{12}$$

$$if\ \hat{q}_{i,t-1} < \hat{q}^e_{i,t-1}\ \ and\ q^{tot}_{i,t-1} > \hat{q}_{i,t-1} : \begin{cases} \hat{q}^e_{i,t} = \hat{q}^e_{i,t}(1 - U[0, \delta]) \\ p_{i,t} = p_{i,t-1}(1 - U[0, \delta]) \end{cases} \tag{13}$$

$$if\ \hat{q}_{i,t-1} < \hat{q}^e_{i,t-1}\ \ and\ q^{tot}_{i,t-1} = \hat{q}_{i,t-1} : \begin{cases} \hat{q}^e_{i,t} = \hat{q}^e_{i,t-1} \\ p_{i,t} = p_{i,t-1} \end{cases} \tag{14}$$

The logic of this scheme is pretty straightforward: Equation 12 states that if past sales were greater than their expected value, firms increase both their sales expectations and selling price. Equation 13, instead, implies that if past sales were below their expected value due to a lack of demand for the firm's output (i.e., goods available for sale were higher than actual sales), both expectations and prices are revised downward. Finally (equation 14), in the case where past sales were below expectations but all the goods were sold, thereby suggesting that sales were constrained by supply, firms postpone any decision about revising prices and expectations to the next period.

[8] Indeed, for simplicity reasons, we assume households cannot liquidate their participations in firms and banks.

In order to avoid firms producing at a loss, prices have a lower bound given by the unit costs of production: $p_{i,t} \geq \frac{w_{i,t}}{\phi_{i,t}}$, where $w_{i,t}$ is the full-time wage paid by the firm, and $\phi_{i,t}$ is their labor productivity in period t.

Firm's labor demand is simply obtained by dividing planned levels of production by the productivity of labor employed by the firm: $l^D_{i,t} = q^D_{i,t}/\phi_{i,t}$. Actual production may end up being lower than desired when workers are less than needed, either because firms are not able to attract enough workers at the offered wage or because they do not have enough financial resources to pay them.

The salary offered by firms, $w_{i,t}$, is adaptively revised from period to period following a logic similar to that characterizing workers' reservation wage. First, firms check whether they have succeeded in filling all vacant positions during the previous period by comparing their past labor demand $l^D_{i,t-1}$ and the number of workers actually employed $l_{i,t-1}$. When this difference is positive, they consider raising the offered salary to make their vacant positions more attractive. Otherwise, they consider reducing the wage offered to increase their profit margin. As with workers, the probability of these revisions depends on the level of unemployment: reducing wages when unemployment is low exposes the firm to the risk of ending up being labor-constrained, while this is just a remote possibility if many workers are unemployed.

$$w_{i,t} = \begin{cases} w_{i,t-1}(1 + U[0,\delta]), & \text{if } l^D_{i,t-1} - l_{i,t-1} > 0 \text{ with } Pr(w^+_{i,t}) = \upsilon_F e^{-\upsilon u_{t-1}} \\ w_{i,t-1}(1 - U[0,\delta]), & \text{if } l^D_{i,t-1} - l_{i,t-1} = 0 \text{ with } Pr(w^-_{i,t}) = 1 - \upsilon_F e^{-\upsilon u_{t-1}} \end{cases} \tag{15}$$

Lowering wages is not the only way to increase profit margins. By investing in in R&D activities, in fact, firms can improve their productivity $\phi_{i,t}$, thereby reducing unit costs of production. Firms invest in R&D a constant share of what they expect to spend for production:

$$R\&D^D_{i,t} = \gamma w_{i,t} l^D_{i,t} \tag{16}$$

As maintained by equation 2, R&D is carried out by workers and funds dedicated to this activity add to their salary. Therefore, actual $R\&D_{i,t}$ needed.

By investing more in R&D firms increase their probability of rising their labor productivity either by achieving incremental innovations or by exploiting sectoral spillovers through imitation of competitors. Both types of innovation activities are modeled along the evolutionary lines of Nelson and Winter (1977a, 1982), recovered and refined by Dosi et al. (2010) and many others (see, for example Caiani et al., 2018b, 2020).

For simplicity, we assume the probability of success in innovating and imitating to be equal. For tradable firms, this probability is given by:

$$Pr^T_{success_{i,t}} = 1 - e^{\frac{-\nu R\&D_{i,t}}{\Phi^T_t P^T_t}} \tag{17}$$

In equation 17, P^T_t is the average international price of tradables and Φ^T_t is the average labor productivity of tradable firms in the Monetary Union. Both are calculated as a weighted average, with weights represented by firms' market shares. Therefore, equation 17 states that the probability of success is a non-linear increasing function of the real investment in R&D, $R\&D_{i,t}/P^T_t$, divided by the sector average level of productivity Φ^T_t. This latter correction is required to prevent $Pr_{success_{i,t}}$ from growing with the higher levels of productivity attained during the simulations.[9]

[9] Although there is no indexation of wages to prices or productivity levels, any stable configuration of the

The probability of success for non-tradable firms follows the same logic:

$$Pr^{NT}_{success_{i,t}} = 1 - e^{\frac{-\nu R\&D_{i,t}}{\Phi^{NT}_t P^{NT}_t}} \tag{18}$$

where P^{NT}_t is the average domestic price of non-tradable goods and Φ^{NT}_t is the national average labor productivity of non-tradable firms, both being weighted for firms' market shares.

When successful in innovating, firms are allowed to sample a positive productivity increase:

$$\phi_{i,t+1} = \phi_{i,t}(1 + U[0, \delta]) \tag{19}$$

Firms having a level of productivity below the average can also exploit sectoral spillovers to narrow the gap with the standards of production in the sector. If successful, they can recover a randomly drawn share between 0 and χ of the productivity gap that they currently suffer compared to the average of the sector.

For tradable firms:

$$\phi_{i,t+1} = \phi_{i,t} + U[0, \chi(\Phi^T_t - \phi_{i,t})] \ \textit{if} \ \phi_{i,t} < \Phi^T_t \tag{20}$$

For non-tradable producers:

$$\phi_{i,t+1} = \phi_{i,t} + U[0, \chi(\Phi^{NT}_t - \phi_{i,t})] \ \textit{if} \ \phi_{i,t} < \Phi^{NT}_t \tag{21}$$

Successful R&D efforts are assumed to exert their positive effect on labor productivity starting from the next period.

Firms use both internal funds and external funding in the form of loans asked to domestic and foreign banks (L_{it}). Following Meyers (1984), firms resort to bank credit after internal funds have been exhausted, since the cost of external finance is usually higher due to market imperfections and information asymmetries.

This also implies that firms resort to credit if its cost is smaller than the expected additional revenues coming from the additional supply producible with those funds, given selling prices and sales expectations.

When this condition holds, the quantity of loans demanded by firms is thus equal to expenses minus internal funds:

$$L^D_{i,t} = \begin{cases} w_{i,t} l^D_{i,t} + R\&D^D_{i,t} - D_{i,t}, & \text{if } w_{i,t} l^D_{i,t} + R\&D^D_{i,t} > D_{i,t} \\ 0, & \text{if } w_{i,t} l^D_{i,t} + R\&D^D_{i,t} \leq D_{i,t} \end{cases} \tag{22}$$

Firms can ask credit to several banks until they have satisfied their demand, but they may nonetheless end up being financially constrained. In this case, firms prioritize production over R&D. Following a fairly common simplifying assumption in macro ABMs, loans are repaid, together with the interests accrued, at the end of the period in which they have been granted.

Just like households, also firms deposit their funds at a randomly selected bank, accruing an interest $r_{d,t}$.

Firms' profits are the sum of revenues from sales, interests on deposits, and the nominal variation of inventories, minus wages paid to workers, R&D expenses, and interests on credit:

model requires the purchasing power of households and productivity not to diverge for too long. Otherwise, this would cause either a never-ending inflationary spiral or a total collapse of the economy, depending on which of the two grows faster. To avoid a massive unemployment situation, the growth of real wages should allow for the absorption of the rising quantities producible thanks to the rise of productivity levels. Since nominal wages enters linearly in the determination of R&D, this latter also tends to rise with prices and productivity. Therefore, to maintain the same efficacy of R&D for a given effort by the firm, we need to divide nominal R&D investments for both prices and productivity levels in equation 17 (see also Caiani et al., 2018a).

$$\pi_{i,t} = p_{i,t}q_{i,t} + r_{d,t}D_{it} + \Delta INV_{i,t} - w_{i,t}l_{i,t} - R\&D_{i,t} - r_{i,t}L_{i,t} \tag{23}$$

Firms' net operating cash flows, which determine the evolution of internal funds and are indicated by $\pi^*_{i,t}$ can be obtained by subtracting the variation of inventories from the definition of profits. When $\pi^*_{i,t} > 0$, firms pay taxes ($T^{\pi}_{i,t}$) and distribute dividends ($Div^{\pi}_{i,t}$) to equity holders, expressed as a share ρ of their net cash inflow.[10]

$$T^{\pi}_{i,t} = \begin{cases} \tau_{k,t}\pi^*_{i,t}, & \text{if } \pi^*_{i,t} > 0 \\ 0, & \text{if } \pi^*_{i,t} \leq 0 \end{cases} \tag{24}$$

$$Div^{\pi}_{i,t} = \begin{cases} \rho(\pi^*_{i,t} - T^{\pi}_{i,t}), & \text{if } \pi^*_{i,t} > 0 \\ 0, & \text{if } \pi^*_{i,t} \leq 0 \end{cases} \tag{25}$$

Dividends are distributed to equity holders proportionally to the share of the firm's equity they hold.

3.1.3 Banks

Banks offer checking accounts to households and firms, paying an interest $r_{d,t}$ equal to a (constant) fraction ζ of the discount rate r_t fixed by the Central Bank of the Monetary Union. In addition, banks provide credit to firms. In order to avoid taking excessive risks, the maximum amount of credit that banks are willing to supply in any given period is a multiple μ_1 of their equity $A_{z,t}$: $L^{DS}_{z,t} = \mu_1 A_{z,t}$

For each loan application received (from both domestic and foreign firms), banks compute a probability $Pr(Loan_{i,t})$ of accepting it and the interest rate ($r_{i,t}$) associated depending on the borrower's riskiness, captured by her implied leverage ($L^D_{i,t}/A_{i,t}$):

$$Pr(Loan_{i,t}) = e^{-\iota_l \frac{L^D_{i,t}}{A_{i,t}}} \tag{26}$$

$$r_{i,t} = \chi \frac{L^D_{i,t}}{A_{i,t}} + r_t \tag{27}$$

Banks are subject to minimal reserve requirements, expressed as a share μ_2 of their deposits: $R^M_{z,t} = \mu_2 D_{z,t}$.

When reserves $R^M_{z,t}$ are below the requirement, banks recover the necessary liquidity by applying to the Central Bank marginal lending facility, receiving cash advances ($L_{zCB,t}$) at the discount rate r_t.

If instead banks have more reserves than needed, the excess liquidity can be used to buy bonds ($B_{zk,t}$) of any member country k, which bring a country-specific interest rate $r_{bk,t}$ (see equation 38). The purchase of bonds, however, is not deterministic: the probability for a bank of purchasing a certain tranche of bonds issued by a given country depends inversely on the debt-to-GDP ratio of this latter:[11]

$$Pr(b_{k,t}) = e^{-\iota_b \frac{B_{k,t}}{Y_{k,t}}} \tag{28}$$

[10] Since taxes and dividends are determined at the end of period t, we assume them to be paid at the beginning of $t+1$.

[11] See Caiani et al. (2018a) for more technical details

Banks' profits are equal to:

$$\pi_{z,t} = \sum_{i,L_{iz,t}>0}^{I_{k,t}} r_{i,t} L_{iz,t} + \sum_{k,B_{zk,t}>0}^{I_{k,t}} r_{bk,t} B_{zk,t} + r_{re} R_{z,t} - BD_{iz,t} - r_{d,t} D_{z,t} - r_t L_{zCB,t} \tag{29}$$

where ($BD_{iz,t}$) stands for 'bad debt' and indicates (possible) non-performing loans due to borrowers' default.

Banks pay taxes on positive profits and distribute to equity holders a share ρ of net profits. Dividends are distributed proportionally to the share of the bank's equity owned.

$$T^{\pi}_{z,t} = \begin{cases} \tau_{k,t} \pi_{z,t}, & \text{if } \pi_{z,t} > 0 \\ 0, & \text{if } \pi_{z,t} \leq 0 \end{cases} \tag{30}$$

$$Div^{\pi}_{z,t} = \begin{cases} \rho(\pi_{z,t} - T^{\pi}_{z,t}), & \text{if } \pi_{z,t} > 0 \\ 0, & \text{if } \pi_{z,t} \leq 0 \end{cases} \tag{31}$$

3.1.4 Central Banks

The Union Central Bank sets the discount interest rate following a Taylor rule based on the average level of inflation across member countries (Taylor, 1993; Smets and Wouters, 2007; Gerali et al., 2010):

$$r_t = \bar{r}(1-\xi) + \xi r_{t-1} + (1-\xi)\xi^{\Delta P}(\Delta P_{t-1} - \overline{\Delta P}) \tag{32}$$

Here, $\bar{r}$ is the exogenous long-run interest rate, ξ is the parameter defining the speed of adjustment, $\xi^{\Delta P}$ is the sensitivity to inflation, ΔP_{t-1} is the average level of inflation, and $\overline{\Delta P}$ is the inflation target.

National Central Banks act on behalf of the Union Central Bank: they provide liquidity to domestic banks through the lending facility ($L_{CBk,t}$), hold the reserves of domestic banks ($R_{CBk,t}$), and purchase the government bonds of their country ($B_{CBk,t}$), which may be left over after private banks' purchases.

National Central Banks' profits are thus equal to $\pi_{CBk,t} = r_{bk,t} B_{CBk,t} + r_t L_{CBk,t} - r_{re} R_{CBk,t}$ and, as it mostly happens in reality, are automatically redistributed to the national government.

3.1.5 Government

National governments collect income taxes from households (h) and taxes on past-period profits from firms (i) and banks (z). Total taxes $T_{k,t}$ are then equal to:

$$T_{k,t} = \sum_{h,y_{h,t}>0}^{H_k} \tau_{k,t} y_{h,t} + \sum_{i,\pi^*>0}^{I_k} \tau_{k,t} \pi_{i,t-1} + \sum_{z,\pi>0}^{Z_k} \tau_{k,t} \pi_{z,t-1} \tag{33}$$

Public spending $G_{k,t}$ is a lump-sum, equally-distributed monetary transfer to each households ($G_{k,t}/H$).

When the difference between revenues from taxes and government spending is negative, the government runs a deficit, which is financed by issuing bonds on the financial market. Conversely, budget surpluses $SU_{k,t-1}$ generate savings to fund future expenditures, thereby reducing the quantity of bonds to be issued in the future.

iIn each period, public spending ($G_{k,t}$) and tax rates ($\tau_{k,t}$) are set by the government following a simple adaptive algorithm which compares desired and past levels of public expenditure on the one hand, and expected and admissible levels of public deficit on the other hand. In order to keep the magnitude of desired public spending stable relative to GDP, its value is set by updating its exogenous initial value G to account for inflation and the rise in the productive capacity of the national economy, which reflects the rise in productivity levels. That is, $G^D_{k,t} = P_{k,t}\Phi_{k,t}G$, where $P_{k,t}$ and $\Phi_{k,t}$ represent, respectively, the average price and productivity of the country. However, in planning their fiscal policy, governments are also committed to the Union fiscal rules that mandate not exceeding a certain deficit-to-GDP threshold indicated by the parameter d^{max}. Actual public spending and tax rates are then revised as follows:[12]

$$if\ d_{k,t-1} \geq d^{max}\ \ and\ G^D_{k,t} \leq G_{k,t-1} : \begin{cases} G_{k,t} = G_{k,t-1}(1 - U[0, \delta_G]) \\ \tau_{k,t+1} = \tau_{k,t}(1 + U[0, \delta_G]) \end{cases} \tag{34}$$

$$if\ d_{k,t-1} \geq d^{max}\ \ and\ G^D_{k,t} > G_{k,t-1} : \begin{cases} G_{k,t} = G_{k,t-1} \\ \tau_{k,t+1} = \tau_{k,t}(1 + U[0, \delta_G]) \end{cases} \tag{35}$$

$$if\ d_{k,t-1} < d^{max}\ \ and\ G^D_{k,t} \leq G_{k,t-1} : \begin{cases} G_{k,t} = G_{k,t-1}(1 - U[0, \delta_G]) \\ \tau_{k,t+1} = \tau_{k,t}(1 - U[0, \delta_G]) \end{cases} \tag{36}$$

$$if\ d_{k,t-1} < d^{max}\ \ and\ G^D_{k,t} > G_{k,t-1} : \begin{cases} G_{k,t} = G_{k,t-1}(1 + U[0, \delta_G]) \\ \tau_{k,t+1} = \tau_{k,t} \end{cases} \tag{37}$$

If the past period deficit-to-GDP ratio was above the maximum admissible level and today's desired spending is lower than the past period spending, taxes are raised, and spending is cut (34) in the hope of bringing the deficit-to-GDP ratio into the admissible area. However, if the government desires to increase spending (35), only tax rates are lifted, whereas spending sticks to its previous period level. When the past deficit-to-GDP ratio was instead compliant with the Union fiscal rules, and the government aspires nonetheless to cut spending (36), both spending and tax rates are revised downward. If the government instead wants to increase public spending, this can be done, but taxes are kept equal to the previous period so as to mitigate the risk of infringing the deficit rule (i.e., exceeding d^{max}) in the current period.

During each simulation round, national governments repay bonds previously issued and pay interests to bond holders. The interest rate on bonds is set as a premium on the Central Bank discount rate depending on the debt-to-GDP ratio of the country:

$$r_{bk,t} = \chi B_{k,t}/Y_{k,t} + r_t \tag{38}$$

Finally, national governments step in to guarantee depositors in case of a default by a domestic bank: the governments issues an additional batch of bonds directly purchased by the Central Bank, using the liquidity collected to reimburse the depositors who suffered a loss.

3.1.6 Firms' and banks' endogenous entry and exit

As in previous versions, the model features an endogenous entry-exit process of firms and banks. The determinants of households' investment in the creation of new firms and banks are explained in section 3.1.1.

[12] In addition, in order to avoid both unreasonably high and low levels of spending and taxes, the tax rate is bound to vary within the range $\{\tau_{min}, \tau_{max}\}$, and $G_{k,t}$ is bound between a minimum and maximum share of GDP: $\{g_{min}Y_{k,t}, g_{max}Y_{k,t}\}$.

To determine the type of new business created, we employ a simplified rule of thumb aimed at avoiding an excessive imbalance in the relative dimension of the banking and non-financial sectors: the new entrant will hence be a bank if the dimension of the banking sector (measured by the sector's net worth and by the number of active firms) relative to non-financial firms is below a given percentage η, otherwise, the new entrant will be a non-financial firm. A similar rule is adopted to ensure that the relative dimension of the tradable and non-tradable sectors is consistent with the distribution of consumption demand between tradables and non-tradables. Every new non-financial firm will be a tradable with probability equal to c_T, the parameter defining the share of consumption devoted to tradables (see equation 5), and a non-tradable otherwise.

The condition set for the actual entrance of a new firm or bank, however, requires that the funds invested by households in the period exceed a threshold initial equity level, which is randomly sampled in the range between the net worth of the smallest and largest incumbents. The first randomly ordered households that, with their investment, allow to exceed this threshold, become the new entrant's shareholders. Please note that, if funds invested by households are high enough, more than one firm (or bank) can possibly enter the market within the same period. When the threshold is not met, funds originally invested are hoarded by households to fund investment in the following period.

The features of the new entrants depend on the features of incumbent firms. For non-financial firms, the initial productivity is a random sample between the lowest and highest values of incumbents. The initial price ($p_{i,t}$) and the initial offered wage ($w_{i,t}$) are assumed to be equal to the sector average. Finally, initial sales expectations are the minimum between the amount of goods producible given the firm's initial equity, offered wage, and productivity (i.e., $\frac{A_{i,t}}{w_{i,t}}\phi_{i,t}$) and a random sample between the lowest and highest sales expectations of incumbents.

Firms default whenever they have no funds to pay for the salary $w_{i,t}$ of at least one worker, and hence they cannot produce. Similarly, banks whose net-worth falls below the national average wage default.

Defaults by firms imply a loss for exposed lending banks due to non-performing loans. If high enough, these losses may cause a default of the banks. In this case, the government is assumed to step in to reimburse depositors, as explained in section 3.1.5.

3.2 Adding a Union Budget

In the baseline configuration of the model, fiscal policy is entirely the responsibility of national governments. Thus, the baseline simulates an institutional framework in which Union-level fiscal policies play no significant role, except for defining the budget rules that national governments should abide. In addition to the baseline, we introduce two alternative institutional settings: an Intergovernmental Fiscal Transfer Union (IFTU) where the Union Budget is only financed via national contributions funded by taxes, and a Fully-Fledged Fiscal Transfer Union (FFFTU) which envisages the possibility of issuing common debt in the form of Union Bonds to fund the Union Budget.

3.2.1 The Intergovernmental Fiscal Transfer Union

In the IFTU, each country contributes to the Union budget by diverting a part of its tax revenues equivalent to a percentage α of the country's GDP to it. Accordingly, desired and actual public spending are reduced by the same amount in the period when the IFTU is introduced, and follow the usual adaptive fiscal rule described in section 3.1.5 from then on. In other words, national

countries decide to delegate a part of their fiscal budget to the Union.[13]

While national contributions to the common budget are proportional to countries' GDP levels, the funds are then redistributed according to a rule that embeds a redistributive principle based on the cyclical performance of countries. Formally, each country k gets a share of the Union Budget $R_{k,t}$ defined as:

$$R_{k,t} = \frac{1}{K}\left(1 + \frac{\bar{g}_t - g_{k,t}}{\sum_k |\bar{g}_t - g_{k,t}|}\right) \tag{39}$$

where $g_{k,t}$, representing the percentage deviation from the country's GDP growth trend, is a country-specific measure of the cyclical phase, and $\bar{g}_t$ is the average across countries of this measure. The rule thus implies that countries performing worse than the Union average in cyclical terms receive more, while those performing better receive less, thereby entailing also a stabilizing principle besides the redistributive one.[14]

The mechanism devised in the paper is very close in spirit to the proposal for a European fiscal stabilization capacity made by the IMF in Arnold et al. (2018) which foresees a macroeconomic stabilization fund financed by annual contributions from countries that are used to build up assets in good times and make transfers to countries in bad times. It is also important to notice that the mechanism does not derogate from compliance with EU fiscal rules thereby mitigating moral hazard risks. Finally, similarly to Arnold et al. (2018), devising a formal rule such as 40 with a focus on the relative cyclical performance of countries rather than on their relative GDP levels brings several advantages: it enhances the counter-cyclical stabilization objective of the scheme, it avoids permanent transfers between countries, and makes it function as automatically as possible to limit the scope for disputes over its operation.

3.2.2 The Fully-Fledged Fiscal Transfer Union with Common Debt

The FFFTU follows the same rules as the IFTU for determining national contributions to the Union budget and its allocation across countries. However, the Union can now run deficits and issue common debt instruments, Union Bonds, which means that the budget to be allocated is no longer constrained by the funds collected through national contributions.

[13] Alternatively, one could assume financing national contributions to the Union budget through an additional tax proportional to GDP, to be levied on top of those already existing while keeping the level of national public expenditure constant. We also considered this alternative specification as a robustness check and found that the results did not change in any significant way. This observation is not surprising if we consider that public spending in the model takes the form of money transfers to households, and that net transfers at the national level between the household sector and the government do not significantly change whether we assume to divert part of current tax revenues to the Union budget without touching tax rates and then reduce public spending accordingly, or we instead raise additional taxes for the same amount and keep public spending constant.

[14] This rule can be interpreted as a special case of a more general rule in which a portion of the budget is distributed based on the described redistributive principle, and the rest is allocated based on the weight of national GDPs in the Union GDP, which determines the relative magnitude of national contributions to the Union budget:

$$R_{k,t} = (1 - \alpha_{UB})\frac{Y_{k,t}}{\sum_k Y_{k,t}} + \alpha_{UB}\frac{1}{K}\left(1 + \frac{\bar{g}_t - g_{k,t}}{\sum_k |\bar{g}_t - g_{k,t}|}\right) \tag{40}$$

α_{UB} and $1-\alpha_{UB}$ are the weights given to the redistributive principle and to the dimension of national contributions in determining countries' budget allocation shares. $\alpha_{UB} = 1$ corresponds to the purely redistributive case. Besides the specific interest in testing an explicitly redistributive rule, the decision to focus on this latter case comes from the fact that the other component of the allocation rule, which depends on countries' GDP shares, just tends to give back to households funds that were previously subtracted from their availability through the Union Budget dedicated tax. Therefore, there is not much difference in terms of model results between considering a bigger budget, of which a portion $1-\alpha_{UB}$ is given back to countries proportionally to their original contributions, and focusing instead just on the redistributive component by assuming a smaller budget. This second option was hence preferred as it avoids a possible source of noise in the results.

The dimension of the Union fiscal budget is determined by an adaptive rule that, just like the correspondent rule for individual countries, aims to achieve two objectives: to maintain the fiscal budget roughly stable compared to GDP, despite possible fluctuations in national contributions due to the cycle, and to avoid excessive debt accumulation, i.e., to keep the public debt/GDP ratio of the Union relatively stable.

To this end, we start by defining a desired budget to be allocated in each period t as:

$$G^D_{U,t} = P_t \Phi_t G_U \tag{41}$$

G_U is a fixed real amount defined at the beginning of the simulation as a share α of the potential real GDP producible in the initial period (given the number of workers and their initial unitary productivity), where α is the same parameter that defines the magnitude of national contributions to the Union budget expressed as a share of GDP. This amount G_U is then adjusted based on the average price (P_t) and productivity (Φ_t) levels to keep the desired spending roughly stable compared to Union GDP.

We also assume a target deficit threshold, as a percentage of the total contributions collected by member countries in the period, that the IFTU tries not to exceed d^*_U.

The actual budget allocated, $G_{U,t}$, is then determined according to the following adaptive rule:

$$G_{U,t} = \begin{cases} G_{U,t-1}\left(1 - U[0, \delta_G]\right) & \text{if } G^D_{U,t} \leq G_{U,t-1} \\ G_{U,t-1} & \text{if } d_{U,t-1} \geq d^*_U \text{ and } G^D_{U,t} > G_{U,t-1} \\ G_{U,t} = G_{U,t-1}\left(1 + U[0, \delta_G]\right) & \text{if } d_{U,t-1} < d^*_U \text{ and } G^D_{U,t} > G_{U,t-1} \end{cases} \tag{42}$$

where $d_{U,t-1}$ is the Union deficit (or surplus) experienced in period $t-1$, expressed as a percentage of the funds collected by member countries through taxes.

Finally, the rate of interest paid on Union bonds is increasing in the Union debt-to-GDP ratio, following the same rule employed for individual countries.

4 Results: the introduction of the IFTU and FFFTU

This section discusses the effects of the introduction of an IFTU financed through national taxes and an FFFTU with the additional possibility of issuing common debt, which are assumed to occur in period 500. For explanatory reasons, results are presented for the case of a Monetary Union composed of five countries. Appendix B, however, discusses their robustness when changing the number of countries.

The top line of panel 2 shows that moving to either an IFTU or an FFFTU, where the allocation of funds follows an explicit redistributive rule as described by equation 40, reduces significantly the volatility of GDP and tends to increase average GDP growth rates. The effect tends to be greater for higher values of α, which is when the Union budget is comparatively bigger. Accordingly, the probability of experiencing sharp reductions of GDP decreases as well (center line-left side of panel 2). With the improvement in the GDP performance also comes an improvement in average unemployment levels and, also in this case, the effect tends to be greater for bigger values of α. These figures also display that the FFFTU tends to perform significantly better than the simple IFTU, thanks to the greater flexibility provided by the possibility of running deficits at Union level funded through the issuance of union bonds. This, in fact, allows keeping the budget more stable when countries are facing a negative phase of the cycle that may reduce the amount of funds collected through taxes.

However, the impact on the stability of public finance should also be carefully assessed. For this purpose, we asked whether this improved real performance comes at the price of higher public

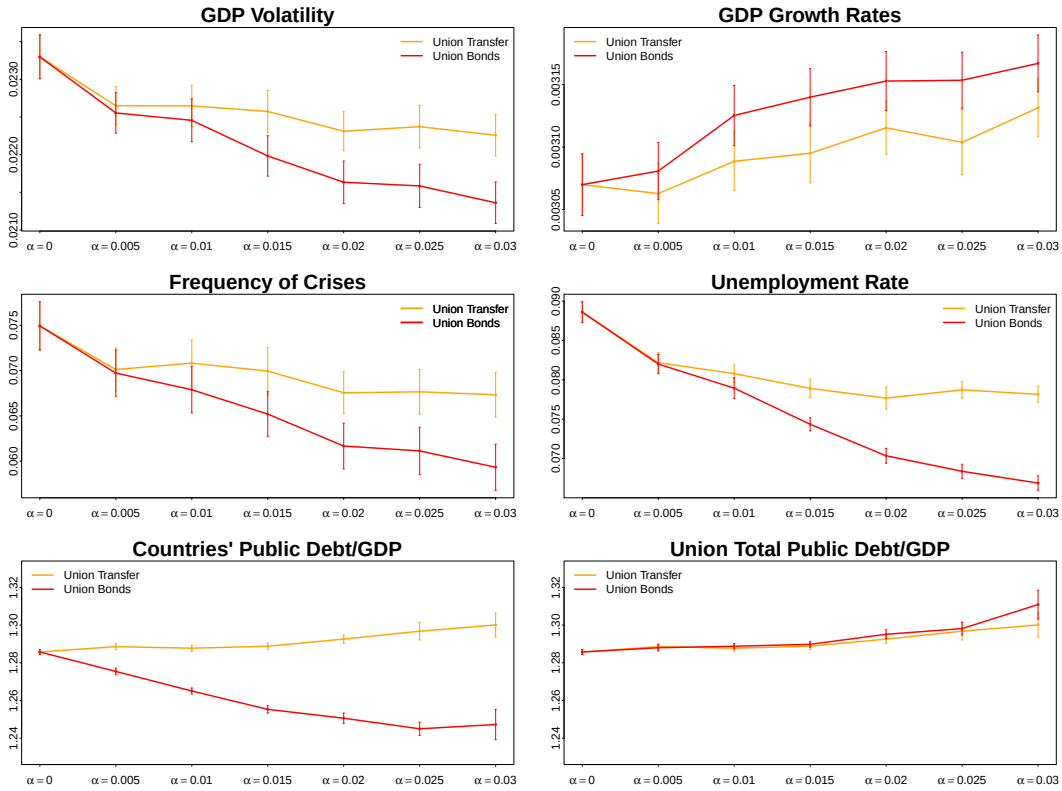

Figure 2: The figure shows the Monte Carlo averages and standard deviations of the displayed variables. The horizontal axis shows the value of α employed in each scenario, which determines the magnitude of national contributions to the Union budget expressed as a percentage of GDP. The left-side case in each plot, i.e., $\alpha = 0$, represents the scenario in which there is no spending at the Union level, and the fiscal policy is solely in charge of national governments, which serves as a baseline. The yellow lines refer to the IFTU case, while the red lines refer to the FFFTU. From the top-left: countries' average standard deviation of real GDP, countries' average real GDP growth rates, countries' average frequency of occurrence of a major crisis (arbitrarily defined as a contraction of real GDP greater than 3%), countries' average unemployment rate, countries' average public debt-to-GDP levels, and finally, the total debt-to-Union GDP level.

debt-to-GDP ratios. The bottom line of panel 2 shows that the impact of an IFTU on average and total debt-to-GDP ratios is either not statistically significant at all or, when significant, still negligible in terms of magnitude. Something similar happens in the case of an FFFTU, though in this latter case, we also observe a partial substitution of national debts with the Union debt, as the former slightly tends to decrease as the Union starts to issue its common debt instruments. The bottom-right figure in panel 2, however, shows that this beneficial side-effect for countries' public finance and the specular accumulation of debt by the Union are not associated with a significant increase in total debt levels. We can hence conclude that neither the IFTU nor the FFFTU seems to bring significant threats to the financial stability of the public sector at either the country or Union level.

Both the IFTU and the FFFTU produce these results by mainly operating as stabilizers,

shifting resources towards countries that are performing worse than the average and thereby providing support to their income and demand. This directly helps to mitigate the worsening of entrepreneurial expectations in those countries, which could possibly lead to further contractions of the level of activity. Even more importantly, since a significant portion of demand is devoted to tradables, the support provided by such a mechanism to the demand of countries performing relatively worse eventually ends up sustaining the demand for exports produced by other countries, including those that are net contributors to the budget (as displayed in Figure 3). In this way, it defuses a major possible contagion channel through international trade, allowing the process of development to unfold along a smoother trajectory. Such a result emerges from a mechanism similar to that highlighted in Gräbner-Radkowitsch et al. (2022), who, using a Stock-Flow Consistent Macro model, show that if the South is allowed to conduct counter-cyclical fiscal policy, it stabilizes output in the South as well as in the North.

Our results suggest how both the redistribution of funds in favor of relatively poorly performing countries in both institutional settings and the further possibility of issuing debt at the European level allowed by the FFFTU help to soften the procyclicality of fiscal policies. This has been increasingly recognized as a possible source of instability for the economy (Gootjes and de Haan, 2022). According to Woo (2009), procyclical fiscal policies tend to increase the volatility of output and dampen GDP growth. These threats are likely to be amplified in the European context (Eyraud et al., 2017) where, due to high economic integration, fiscal policies adopted by certain countries may have significant spillovers to other member states' economies that are often overlooked. Hence, procyclical fiscal policies may undermine the sustainability of public finances in European countries.

4.1 Political feasibility: core *vs* periphery

While the average beneficial effects just discussed and the absence of apparent threats to public finance seem to provide some support for the two proposed institutional settings, we feel it is also important to investigate their political and economic acceptability, which eventually asks us to investigate the specific impacts on different groups of countries. As the institutional history of the European Union clearly demonstrates, the acceptability of a redistributive measure, even when possibly beneficial for the stability of the Union, might be hindered if core countries, characterized by better fundamentals and higher GDP and productivity levels, perceive that this would imply an additional cost for their taxpayers or undermine the resilience of their public finances and the performance of their economy.

For this reason, we disentangle the impacts of the FFFTU policy scheme on higher productivity/higher income countries, which we label as 'core', from the effects on the lower productivity/lower income ones, which we will refer to as 'peripheral'.

The first row of panel 3 shows that the beneficial effects in terms of GDP stabilization and higher growth rates are shared between core and peripheral countries, with core countries being characterized by more stable GDP levels (top-left) and slightly lower growth rates, which indicate a partial catching-up by peripheral countries under all scenarios, including the baseline.

The left-side figure in the center row of panel 3 shows that the probability of experiencing a crisis also falls with the introduction of the FFFTU in both groups of countries, with a greater reduction for higher values of α.

However, despite the similar improvements in GDP dynamics, the center-right figure in panel 3 highlights that the reduction in the average country debt-to-GDP levels following the introduction of the FFFTU, discussed in the previous section (see again panel 2), actually hides diversified dynamics between the core and the periphery. High-income countries tend to experience a significant improvement in their public debt-to-GDP levels after the introduction of

the FFFTU, notwithstanding being net contributors to the Union budget (bottom-right figure in panel 3), whereas the corresponding ratio for low-income countries remains stable or even slightly increases for the highest values of α, despite the fact that they are on average net recipients of Union funds.

This apparent paradox can be explained by looking at the impact exerted by the FFFTU on international trade and by considering that core countries, which mostly coincide with high-productivity countries, are typically more competitive on the common tradable market. In fact, being characterized by lower unit costs of production, their firms can charge lower prices while maintaining the same profit margin as competitors on the internationally integrated tradable market, and they are generally more flexible in reacting to demand swings having more room to lower prices without compromising their profitability.[15]

[15] In Caiani et al. (2018a), the same observation was identified as key to explain the diversified impact of tight and expansionary fiscal policies on high- and low-income countries.

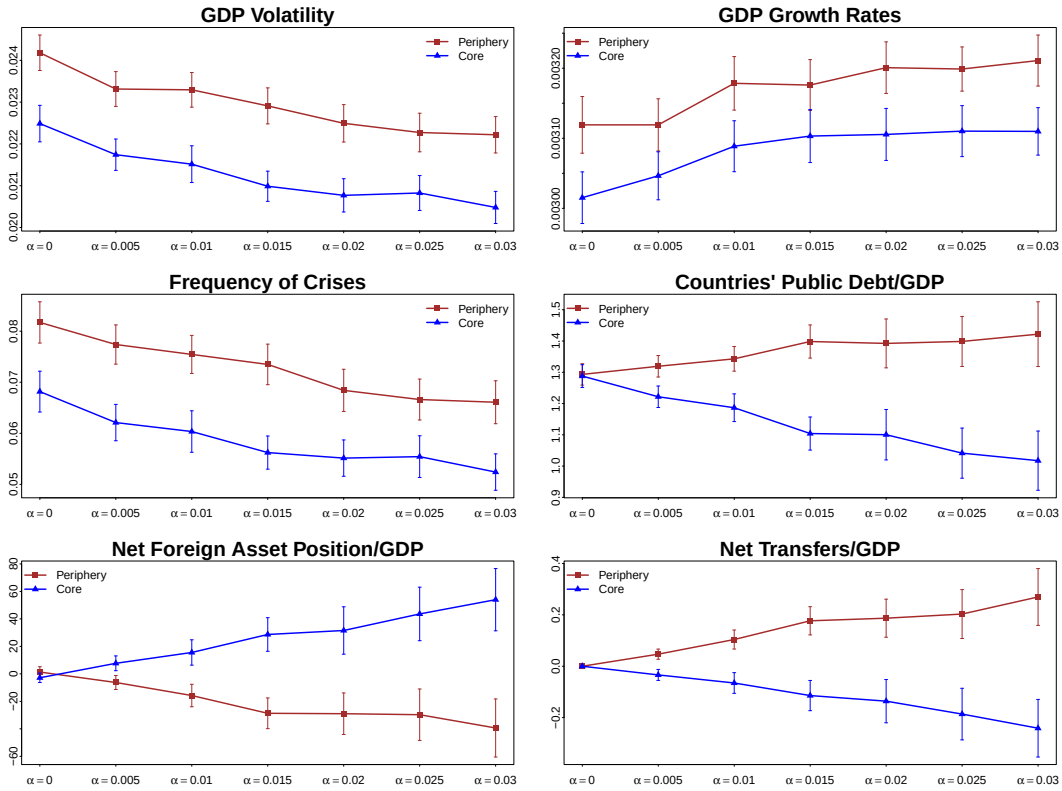

Figure 3: The figure shows the Monte Carlo averages and standard deviations of the displayed variables for higher productivity/higher income (blue lines) countries, labeled as 'core', and lower-productivity/lower-income countries (purple lines), labeled as 'periphery'. The horizontal axes shows the value of α employed in each scenario determining the magnitude of national contributions to the Union budget expressed as a percentage of GDP. The left-side case in each plot, i.e. $\alpha = 0$ represents the baseline scenario in which there is no spending at Union level and the fiscal policy is solely in charge of national governments. From the top-left: countries' average standard deviation of real GDP, countries' average real GDP growth rates, countries' average frequency of occurrence of a major crisis (arbitrarily defined as a contraction of real GDP greater than 3%), countries' average public debt-to-GDP levels, countries' average net foreign asset position (i.e. cumulated Current Account balances), and countries' net position towards the Union budget, defined as the difference between incoming transfers and contributions made to the budget, expressed as a percentage of their GDP.

As a consequence of the greater competitiveness of their tradable firms, core countries tend to benefit more from the stabilizing effect on international trade exerted by the FFFTU. Let us first remind that the distribution of the available budget to individual countries, as described by equation 39, looks only at the cyclical growth of each country and compares it with the 'average' of the Union. Hence, it is the fact that a country performs better or worse than the average in cyclical terms that determines whether it will be a net recipient or a net contributor to the budget, not the level of its income. Being a net-contributor should, in principle, exert a negative effect on domestic aggregate demand, specular to the positive effect exerted in net recipient

countries.

Core and peripheral countries can be both net recipients or net contributors from time to time. However, core countries can derive a double benefit from the introduction of the FFFTU: when they grow less than the average, they are net recipients and benefit from the external support provided by the Union funds. When instead they grow more than the average, they become net contributors but the negative effects brought by such a condition will be partially mitigated by the fact that the funds flowing towards net recipient countries will partly translate into higher demand for tradable goods that will concentrate on more competitive firms, that are mostly located in core countries. Parts of the funds diverted from core countries towards peripheral countries through the redistribution of the FFFTU will hence eventually sustain the exports of the formers, which would have possibly shrunk otherwise. Conversely, peripheral countries can still benefit from the support of the Union when they are in the condition of net recipients, but they lack such a compensation mechanism when they are net contributors.

The mechanism highlighted, on the one hand, implies that the introduction of the FFFTU tends to improve the net-foreign asset position of core countries at the expense of peripheral ones, as one can observe in the left figure in the bottom row of panel 3. However, it also implies that core countries are on average more likely to be net contributors, whereas less-productive countries are more frequently net recipients (see again the bottom-right figure of panel 3). This acts as a sort of balancing mechanism explaining why, notwithstanding the more favorable conditions for core countries, both groups experience a similar improvement in terms of average GDP growth in the long run.

This also allows to explain the diversified dynamics of public finances between the two groups of countries: the improvement of the net foreign asset position of core countries allows them to improve the government balance, thereby reducing their public debt-to-GDP ratios. Conversely, the deterioration of the net-foreign asset position of peripheral countries tends to increase their ratio, although this effect is partially counteracted by the improvement in their GDP dynamics. Thanks to the improvement of GDP growth rates in both groups, the positive effect on core countries tends to outweigh the effect on peripheral ones, explaining the reduction in average public debt-to-GDP levels highlighted in panel 2.[16]

The mechanism highlighted is similar, with some caveats, to that highlighted in Gräbner-Radkowitsch et al. (2022), who consider a scenario where southern countries are allowed to follow a counter-cyclical fiscal policy: deficit spending in the South stabilizes Northern export revenues, thereby allowing the North to accumulate a surplus of financial funds and take a dominant creditor role. While in their experiments, the Northern trade surpluses turn into deficits eventually due to rising consumption demand and higher imports, which does not seem to match the actual developments witnessed in northern countries as acknowledged by the authors, this does not occur in our simulation due to the above balancing effect inherent in the mechanism of redistribution of the IFTU, which makes better-performing countries more likely to be net contributors, thereby mitigating the rise in consumption demand and imports.

Overall, the analysis suggests that an FFFTU with an explicit redistributive dimension based on the cyclical performance of member countries can potentially bring advantages in terms of GDP stabilization and growth that are equally shared across core and peripheral countries, although it tends to produce a shift in trade more favorable to the formers, eventually improving the situation of their public finances. The benefits for core countries thus overcompensate the cost of being, on average, net contributors to the Union budget, thereby providing a solid argument to overcome the political reluctance to accept an explicitly redistributive rule. Concerns may

[16] The existence of a solid inverse relationship between the evolution of the country net foreign asset position and the evolution of public savings and hence the government debt-to-GDP ratio has also been identified and extensively discussed in Caiani et al. (2018a).

instead arise for the effects on the net-foreign asset position of less competitive countries, which also puts upward pressure on their public debt-to-GDP levels. However, this effect is partially lessened by the improvement in their GDP performance, and its magnitude does not seem to constitute a major threat to the financial stability of countries.

In addition, trade imbalances associated with the introduction of the FFFTU and the ensuing divergent dynamics imparted on countries' public debt are partly the consequence of our experiment design where public spending, both at the country and Union level, takes the form of a money transfer to households. This result might instead be attenuated if Union funds were steered towards investment in physical assets and productivity-enhancing activities, thereby possibly fostering a catching up of peripheral countries in terms of productivity levels, which should rebalance trade and countries' net-contributions.

4.2 IFTU and FFFTU facing a demand shock to consumption

While the previous sections have analyzed the effects of the introduction of an IFTU or an FFFTU in 'normal times', we now consider their efficacy in tackling the consequences of an exogenous shock to aggregate demand. More precisely, we apply an exogenous shock to the propensities to consume out of income and wealth, identified by c_y and c_w as in equation 4, in period 750. The shock follows an $AR(1)$ process described by:

$$\begin{cases} \sigma_t = 0.9\sigma_{t-1} + \epsilon_t \\ c_{y,t} = (1-\sigma_t)c_y \\ c_{w,t} = (1-\sigma_t)c_w \end{cases} \tag{43}$$

with $\sigma_{t<750} = 0$, $\epsilon_{t\neq 750} = 0$, and $\epsilon_{t=750} > 0$ representing the original shock. In other words, in period 750 we apply a -10% shock to c_y and c_w that then converge asymptotically to their original values.

Panel 4 displays the dynamics of real GDP and the Public Debt-GDP ratio for different magnitudes of the shock $\epsilon_{t=750}$, respectively expressed in terms of the percentage deviation from their dynamics in the corresponding non-shocked scenarios. For the three experiments with $\epsilon_{t=750} = 5\%, 10\%, 15\%$, we assume the intermediate value $\alpha = 0.015$ to define national contributions to the IFTU and FFFTU budgets.

Results show that the FFFTU, operating as a stabilizer mechanism of international trade, seems to be able to dampen the negative effects brought by the shocks, speeding up the recovery.[17] Results for the IFTU are less unambiguous, suggesting that the redistribution mechanism alone, without the greater fiscal flexibility provided by the possibility to issue common debt, may not be enough to produce a significant beneficial effect when tackling this type of shock.

In all cases, no significant effect of the IFTU and FFFTU on the Union's total level of debt (i.e., considering both national and Union debts) compared to GDP is found.

[17] It is interesting to notice that, for higher values of the shock, the model displays the presence of hysteresis in that GDP levels after the recovery remain lower than in the corresponding non-shocked scenarios.

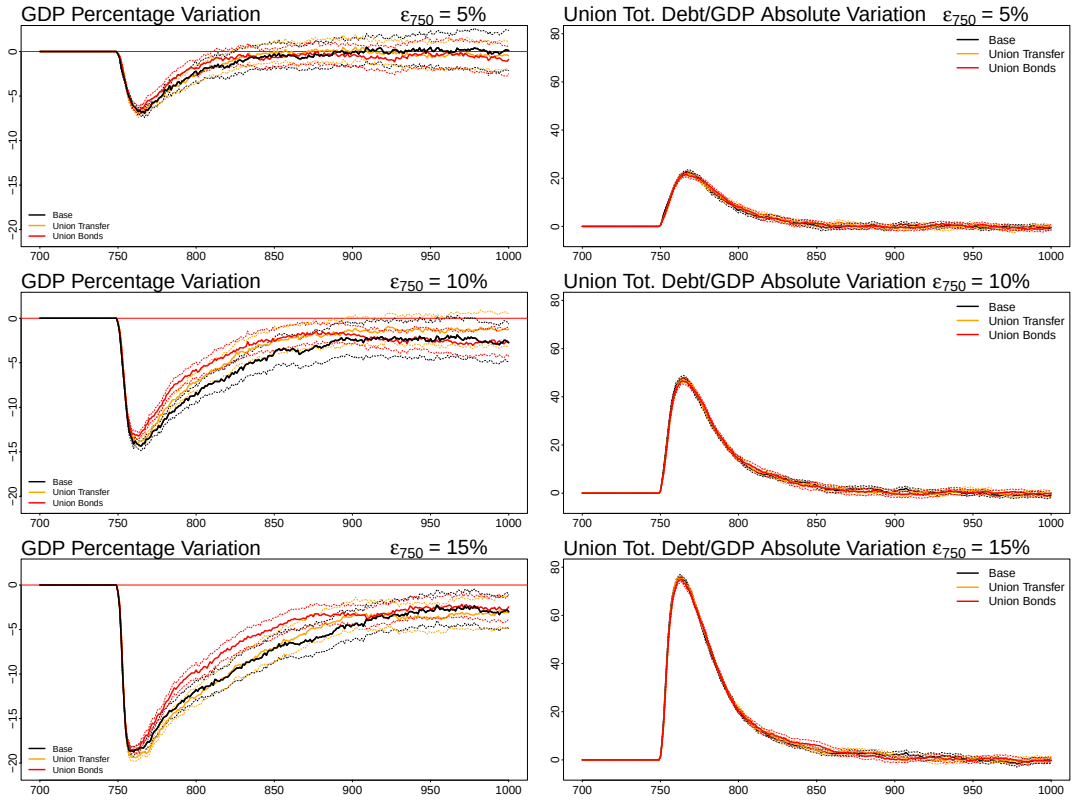

Figure 4: Impact of demand shocks of varying magnitude. Left figures show the Monte Carlo average (percentage) difference in GDP between shocked scenarios and the non-shocked baseline scenario. Right figures show the Monte Carlo average absolute difference in public debt-to-GDP ratios in percentage terms. Dotted lines are the correspondent confidence intervals for the two variables. Black continuous lines refer to the shocked baseline. Yellow lines refer to the shocked-IFTU case. Finally, the red ones refer to the shocked-FFFTU scenario. Simulations assumed an original shock of 5% in the top row, 10% in the center row and 15% in the bottom row. All simulations assumed national contributions equal to $\alpha = 0.015$ of GDP.

To further delve into the analysis, we also investigated the effect of a shock $\epsilon_{t=750} = 10\%$ on c_y and c_w in relation to different sizes of the Union budget, using the same range of values for α employed in Section 4. The upper row of Panel 5 shows that higher values of α allow an FFFTU to reduce both the amplitude of the fluctuations induced by the shock, expressed by the maximum drop in GDP levels (left), and the overall impact of the recession, measured by the induced cumulative GDP loss (right).

The bottom row shows instead that higher values of α allow, on average, a slight limitation of the deterioration of total Public Debt-GDP levels in both the IFTU and FFFTU (right), whereas the FFFTU additionally allows significant reduction of the pressure exerted by the shock on national public finances (left) by shifting part of it at the Union level. As long as the Union debt is perceived as a safer asset compared to debt issued by individual governments, this result implies that an FFFTU might significantly contribute to reducing the risk of a solvency crisis, particularly in the most fragile countries where a debt surge can trigger capital flights

towards the safe harbors offered by stronger economies.

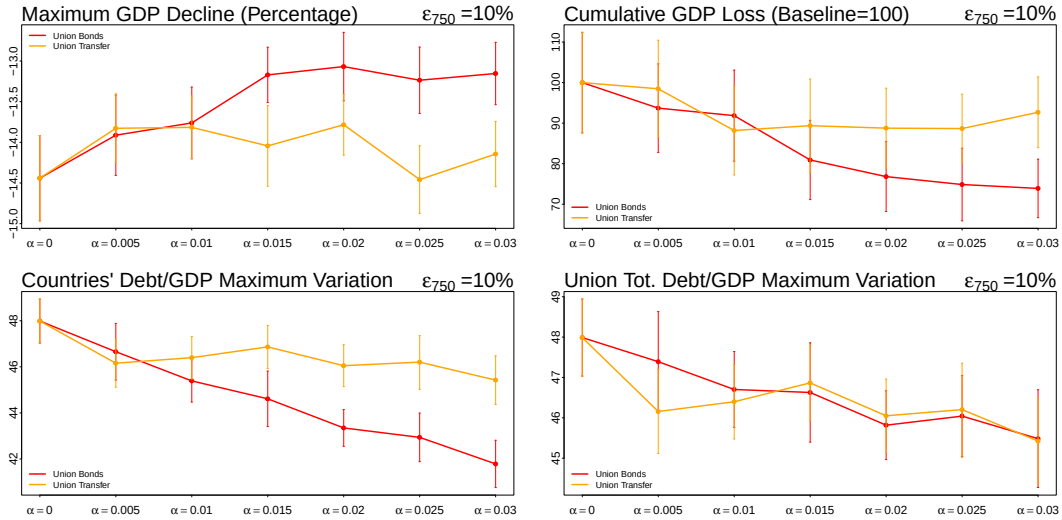

Figure 5: Demand Shock: the panel presents the Monte Carlo averages and standard deviations of the displayed variables following a 10% auto-regressive demand shock occurring in period 750. On the top: the (average) maximum percentage decline in GDP relative to the non-shocked baseline scenario and the cumulated loss in GDP relative to the shocked-baseline scenario (assuming the cumulated loss in the baseline=100). On the bottom: the maximum absolute increase in countries' (average) public debt-to-GDP ratios and the maximum absolute increase in the overall Union public debt-to-GDP ratio. The yellow lines refer to the IFTU case, while the red lines refer to the FFFTU. The horizontal axis shows the value of α employed in each scenario, which determines the magnitude of national contributions to the Union budget expressed as a percentage of GDP. The left-side case in each plot, i.e., $\alpha = 0$, represents the scenario in which there is no spending at the Union level, and the fiscal policy is solely in charge of national governments, which serves as a baseline.

4.3 IFTU and FFFTU facing a supply shock to production

We now consider the efficacy of the two institutional schemes analyzed when facing a supply shock to production. More precisely, we assume that starting from period 750, a certain percentage of the production obtained by each firm is lost as a consequence of an external shock.As before, we model such a shock as an auto-regressive process where the loss experienced in production initially jumps to a certain positive fraction of the total and then slowly goes back to zero, so that the shock asymptotically disappears. As before, we model such a shock as an autoregressive process where the loss experienced in production initially jumps to a certain positive fraction of the total and then slowly goes back to zero, so that the shock asymptotically disappears. Formally, we assume that in each period starting from 750 the output available for sales obtained from the production process is lowered by a fraction σ_t, which is given by:

$$\sigma_t = 0.9\sigma_{t-1} + \epsilon_t \tag{44}$$

(45)

where $\sigma_{t<750} = 0$, $\epsilon_{t\neq750} = 0$ (i.e. no shock before period 750), and $\epsilon_{t=750} > 0$ represents the intensity of the original shock, that is the initial fraction of production lost.

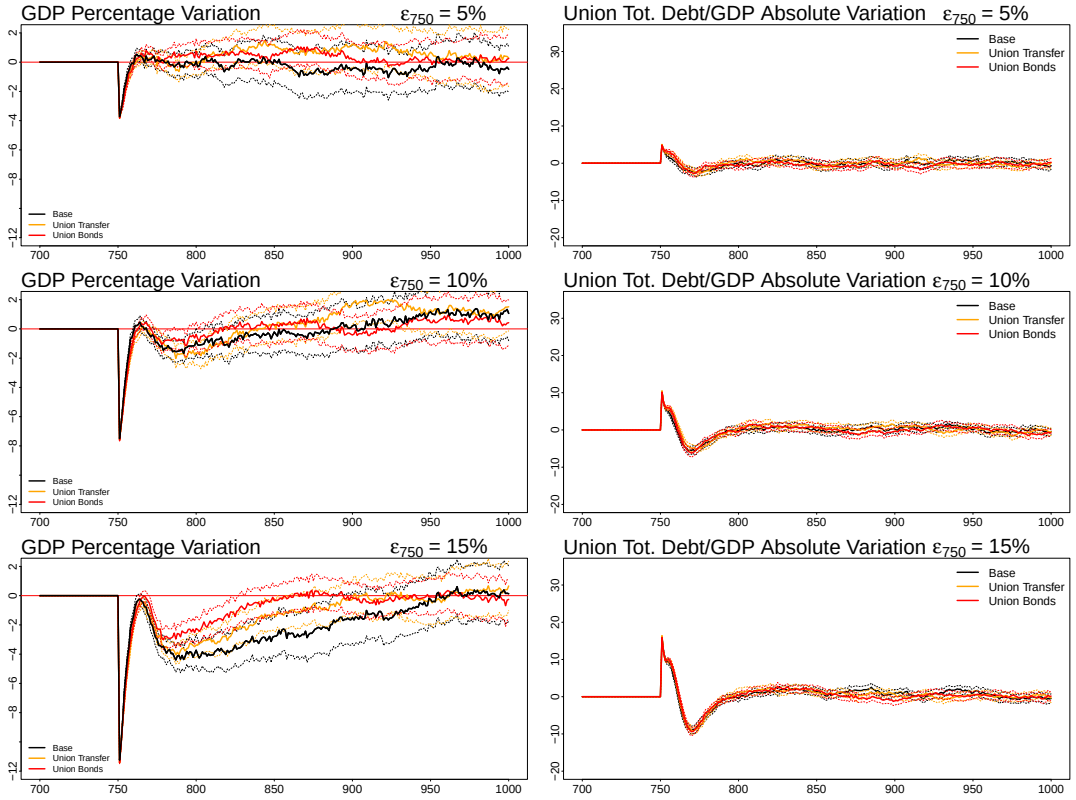

Figure 6: Impact of production shocks of varying magnitude. Left figures show the Monte Carlo average (percentage) difference in real GDP between shocked scenarios and the non-shocked baseline scenario. Right figures show the Monte Carlo average absolute difference in public debt-to-GDP ratios in percentage terms. Dotted lines are the correspondent confidence intervals for the two variables. Black continuous lines refer to the shocked baseline. Yellow lines refer to the shocked-IFTU case. Finally, the red ones refer to the shocked-FFFTU scenario. Simulations assumed an original shock of 5% in the top row, 10% in the center row and 15% in the bottom row. All simulations assumed national contributions equal to $\alpha = 0.015$ of GDP.

Panel 6 displays the dynamics of real GDP and the Public Debt-GDP ratio for different magnitudes of the shock $\epsilon_{t=750}$, respectively expressed in terms of the percentage and absolute deviation from their dynamics in the corresponding non-shocked scenarios. Shocks of $\epsilon_{t=750} = 5\%, 10\%, 15\%$ have been considered. All the simulation displayed employed the intermediate value $\alpha = 0.015$ to define national contributions to the IFTU and FFFTU budgets.

Interestingly, when the shock is significant enough (as shown in the second and third rows of panel 6), a double-dip recession occurs in all institutional settings. Initially, output shrinks as a direct consequence of the shock. However, demand and employment are not immediately affected, leading to the rapid depletion of the buffer of inventories to meet consumer demand. Firms, whose sales expectations are almost unaltered as described in equation 14, then try to

increase the production scale to replenish inventories and counteract the shock, resulting in the hiring of additional workers. Despite the decrease in labor productivity, labor employment increases, temporarily offsetting the direct effect of the production shock. This effect leads to the first recovery observed in the figures on the left side of panel 6. The first recession and subsequent recovery are mirrored, with a delay, by the dynamics of the debt-to-GDP ratio. Initially, the ratio increases as GDP falls, then decreases as GDP eventually overshoots the original variation.

However, over a longer period, another side-effect of the shock tends to drive the dynamics of GDP, leading to the second recession: although the level of activity has returned to its original level, firms have been experiencing increasing unit costs of production due to the dynamics of wages, which are almost unaffected, if not enhanced, while the ex post productivity of labor has shrunk due to the destruction of part of the production.

This results in firms' profit margins being eroded. Weaker firms already exited the market in the immediate aftermath of the shock, where the extinction rate increases by 50% compared to the baseline, and then rapidly jumps back to its normal level. However, in the aftermath of the first recovery, even larger and healthier firms start experiencing difficulties. The default rate increases again by 10%, causing GDP to fall and unemployment to rise, which explains the second recession. Accordingly, the public debt-to-GDP ratio also deteriorates again. As the shock subsides, the entry-exit process stabilizes, and GDP and the level of public indebtedness converge to pre-shock levels over a longer period. It is interesting to note that, since the recession triggered by this shock is driven by a temporary loss of production and by firms' defaults, whereas no depressing effect on individual firms' expectations and desired production levels is observed, also investment in R&D activities by individual firms is preserved. This, in turn, allows technological change to keep up with the corresponding baseline dynamics, and the economy to avoid hysteresis differently from what is observed in the case of a demand shock.

While the economy will eventually converge back to the baseline regardless of the institutional framework as the shock fades away, we still need to assess whether an IFTU or an FFFTU with the fiscal transfer redistribution mechanism proposed can shorten the duration and amplitude of the crisis. Panel 6 shows that only for the biggest shock tested do the two institutional schemes seem to display some efficacy in speeding up the recovery. However, this does not seem enough to draw a conclusion on the usefulness of the two fiscal settings in tackling such a supply shock. Figure 7 indeed shows that both the maximum variation of output and the cumulative loss of GDP do not display a significant monotonic relationship when varying the size of impact exerted by the shock on the public finance, both at the country and union levels (the two plots on the bottom of Figure 7) are minimal.

Overall, this result comes as no surprise as the mechanism devised in the paper is designed to operate as a stabilizer of aggregate demand across the countries of the Union, and there is little reason to expect it to be effective in tackling a supply shock with limited effects on the demand side.

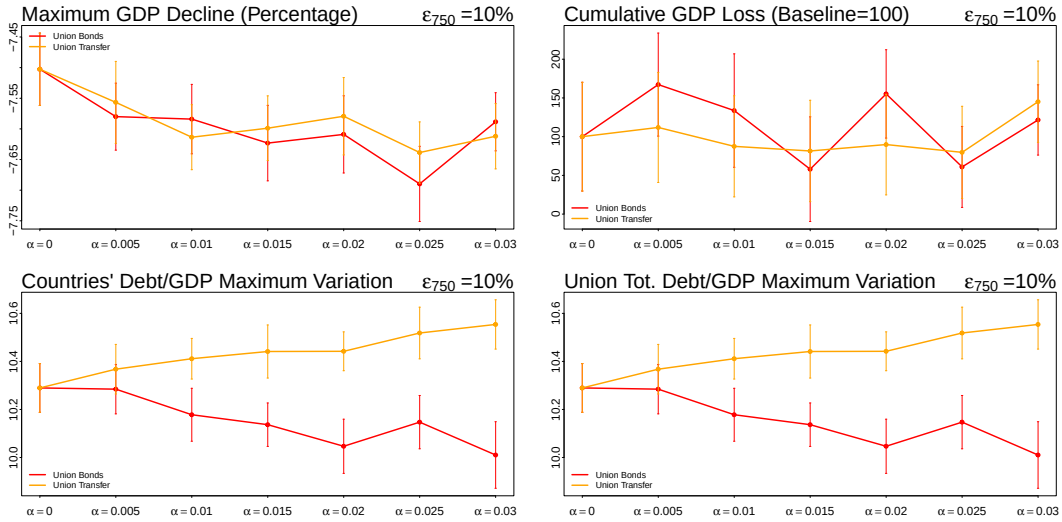

Figure 7: Supply shock: the panel presents the Monte Carlo averages and standard deviations of the displayed variables following a 10% auto-regressive supply shock to production occurring in period 750. On the top: the (average) maximum percentage decline in real GDP relative to the non-shocked baseline scenario and the cumulated loss in real GDP relative to the shocked-baseline scenario (assuming the cumulated loss in the baseline=100). On the bottom: the maximum absolute increase in countries' (average) public debt-to-GDP ratios and the maximum absolute increase in the overall Union public debt-to-GDP ratio. The yellow lines refer to the IFTU case, while the red lines refer to the FFFTU. The horizontal axis shows the value of α employed in each scenario, which determines the magnitude of national contributions to the Union budget expressed as a percentage of GDP. The left-side case in each plot, i.e., $\alpha = 0$, represents the scenario in which there is no spending at the Union level, and the fiscal policy is solely in charge of national governments, which serves as a baseline.

5 Conclusions

The paper investigated the effect of the introduction of an IFTU (Intergovernmental Fiscal Transfer Union) and an FFFTU (Fully Fledged Fiscal Transfer Union) with common debt, where the Union budget allocation follows a redistributive principle based on the relative cyclical performance of member countries. This principle shifts resources from countries performing better to countries displaying worse cyclical performance. The logic of this mechanism is similar to other proposals recently pushed forward in the economic debate, such as Arnold et al. (2018), and mainly operates by stabilizing demand for internationally traded goods, thereby reducing the scope of negative spillovers between highly integrated economies, as also posited by Kenen (1969) and, more recently, by Farhi and Werning (2017). We show that an IFTU and an FFFTU allow to improve economic performance and reduce the volatility of GDP without harming the stability of public finances.

A Fully Fledged Fiscal Transfer Union brings the further advantage of making the Union Budget less dependent on the cyclical performance of national economies, thanks to the possibility of issuing Union bonds. This mechanism mitigates the procyclicality of fiscal policies, which can pose serious threats to the stability of the economy and public finances (Gootjes and

de Haan, 2022; Gräbner-Radkowitsch et al., 2022), particularly in the European context where high economic integration makes fiscal spillovers between countries more pervasive (Eyraud et al., 2017).

Our results also highlight that, despite sharing similar beneficial effects on GDP growth and volatility reduction, core countries tend to benefit more from the introduction of the two schemes, despite being more likely to be net contributors over time. In fact, the stabilization of international demand attained by the two schemes allows them to improve their external position thanks to their greater competitiveness, which eventually reverberates on public savings, allowing them to improve the situation of their public finances. This result has important implications for the 'acceptability' of net fiscal transfers by reversing the argument that the benefits for the Union would be at the expense of more productive countries, suggesting instead that being net contributors might be the consequence of the bigger benefits they accrue thanks to the schemes.

Finally, testing for the efficacy of the two schemes in tackling the consequences of exogenous demand and supply shocks highlights that an FFFTU may help to counteract a demand-induced recession whereas neither the IFTU nor the FFFTU seems to provide clear-cut beneficial effects when facing a supply-induced downturn.

While our results suggest that an IFTU and, even more, an FFFTU may help to stabilize the economy of a Union, some caveats are in order given the simplified nature of the model. First, the model does not consider investment in physical capital and, accordingly, only accounts for disembodied technological change. Additionally, our experiments focus on monetary transfers to consumers as a short-term stabilization mechanism, and so they do not consider transfers at the Union level aimed at funding investment in physical assets or subsidies to support technology-oriented initiatives that would directly affect the supply-side of the economy. Including capital accumulation and accounting for this second kind of fiscal transfers targeted to investment projects can exert non-trivial impacts. For example, additional investments made possible in net recipient countries might contribute to foster a catching-up of peripheral countries in terms of productivity levels. This could allow to absorb trade imbalances within the Union, thereby possibly enhancing the beneficial effects of the two schemes. However, some sort of technological dependence could also emerge, e.g., because low-productivity countries need to import up-to-date vintages of capital from high productivity ones, and this might instead confirm the supremacy of core countries on international trade, and hence their greater benefits from the stabilization of international trade operated by the IFTU and the FFFTU.

Finally, while the financial side of the model presents several novelties within the AB macro literature, such as the inclusion of equity investment, Union bonds and, internationally integrated credit and bond markets, it remains relatively underdeveloped in terms of rules that govern agents' interactions on these markets. Firstly, the matching process in the credit market is largely random since banks are perceived as equivalent by borrowers: depending on their leverage, firms have in fact the same chance of receiving a loan from any bank, domestic or foreign, and expect them to charge the same interest rate. A similar remark holds for the international bond market, where each tranche of bonds issued by a given country has the same probability of being purchased by either domestic or foreign banks. Finally, we do not consider cross-border equity investment. As a result, the model tends to give more emphasis to trade-related factors compared to those related to international financial flows.

References

Arnold, N., Barkbu, B., Ture, H., Wang, H., and Yao, J. (2018). A central fiscal stabilization capacity for the euro area. *IMF Staff Discussion Notes*, 2018(3).

Assenza, T., Colzani, P., Delli Gatti, D., and Grazzini, J. (2018). Does fiscal policy matter? tax, transfer and spend in a macro abm with capital and credit. *Industrial and Corporate Change*, 27-6:1069–1090.

Assenza, T., Delli Gatti, D., and Grazzini, J. (2015). Emergent dynamics of a macroeconomic agent based model with capital and credit. *Journal of Economic Dynamics and Control*, 50:5–28.

Auerbach, A., Gale, W., and Harris, B. (2010). Activist fiscal policy. *Journal of Economic Perspective*, 24(4):141–164.

Axtell, R. and Farmer, J. (2022). Agent-based modeling in economics and finance: Past, present, and future. *Journal of Economic Literature*, forthcoming.

Bandeira, G. (2018). Fiscal transfers in a monetary union with sovereign risk. *Banco de Espana Working Paper*, 1807:45.

Beetsma, R. and Bovenberg, A. (2001). The optimality of a monetary union without a fiscal union. *Journal of Money, Credit and Banking*, 33(2):179–204.

Berger, H., Dell'Ariccia, G., and Ostfeld, M. (2019). Revisiting the economic case for fiscal union in the euro area. *IMF Economic Review*, 67:657–683.

Caiani, A., Catullo, E., and Gallegati, M. (2018a). The Effects of Fiscal Targets in a Monetary Union: a Multi-Country Agent Based-Stock Flow Consistent Model. *Industrial and Corporate Change*, 27-6:1123–1154.

Caiani, A., Catullo, E., and Gallegati, M. (2019). The Effects of Alternative Wage Regimes in a Monetary Union: a Multi-Country Agent Based-Stock Flow Consistent Model. *Journal of Economic Behavior & Organization*, 162:389–416.

Caiani, A., Godin, A., Caverzasi, E., Gallegati, M., Kinsella, S., and Stiglitz, J. E. (2016). Agent Based-Stock Flow Consistent macroeconomics: Towards a benchmark model. *Journal of Economic Dynamics & Control*, 69:375–408.

Caiani, A., Russo, A., and Gallegati, M. (2018b). Does inequality hamper innovation and growth? *Journal of Evolutionary Economics*, Available online, printed version forthcoming:52.

Caiani, A., Russo, A., and Gallegati, M. (2020). Are higher wages good for business? an assessment under alternative innovation and investment scenarios. *Macroeconomic Dynamics*, 24:191–230.

Ciarli, T., Lorentz, A., Savona, M., and Valente, M. (2010). The Effect of Consumption and Production Structure Growth and Distribution. A Micro to Macro Model. *Metroeconomica*, 61(1):180–218.

Cincotti, S., Raberto, M., and Teglio, A. (2010). Credit money and macroeconomic instability in the agent-based model and simulator eurace. *Economics - The Open-Access, Open-Assessment E-Journal*, 4(26).

Constâncio, V. (2020). The return of fiscal policy and the euro area fiscal rule. *Comparative Economic Studies*, 62:358–372.

Crespy, A. and Schramm, L. (2021). Breaking the budgetary taboo: German preferenceformation in the eu's response to the covid-19 crisis. *German Politics*.

Dawid, H. and Dell Gatti, D. (2018). Agent-based macroeconomics. In Hommes, C. and LeBaron,

B., editors, *Handbook of Computational Economics. Vol. 4*, chapter Chapter 2, pages 63–156. Elsevier.

Dawid, H., Gemkow, S., Harting, P., and Neugart, M. (2012a). Labor market integration policies and the convergence of regions: the role of skills and technology diffusion. *Journal of Evolutionary Economics*, 22:543–562.

Dawid, H., Gemkow, S., Harting, P., Van der Hoog, S., and Neugart, M. (2012b). The eurace@ unibi model: An agent-based macroeconomic model for economic policy analysis. *Bielefeld Working Papers in Economics and Managemen*.

Dawid, H., Harting, P., and Neugart, M. (2014). Economic convergence: Policy implications from a heterogeneous agent model. *Journal of Economic Dynamics & Control*, 44:54–80.

Dawid, H., Harting, P., and Neugart, M. (2018a). Cohesion policy and inequality dynamics: Insights from a heterogeneous agents macroeconomic model. *Journal of Economic Behavior & Organization*, forthcoming:–.

Dawid, H., Harting, P., and Neugart, M. (2018b). Fiscal transfers and regional economic growth. *Review of International Economics*, 26-3:651–671.

Deissenberg, C., Van Der Hoog, S., and Dawid, H. (2008). Eurace: A massively parallel agent-based model of the european economy. *Applied Mathematics and Computation*, 204-2:541–552.

D'Erman, V. and Verdun, A. (2018). Introduction: Integration through crises. *Review of European and Russian Affairs*.

Dosi, G., Fagiolo, G., Napoletano, M., and Roventini, A. (2013). Income distribution, credit and fiscal policies in an agent-based keynesian model. *Journal of Economic Dynamics and Control*, 37-8:1598–1625.

Dosi, G., Fagiolo, G., Napoletano, M., Roventini, A., and Treibich, T. (2015). Fiscal and monetary policies in complex evolving economies. *Journal of Economic Dynamics and Control*, 52:166–189.

Dosi, G., Fagiolo, G., and Roventini, A. (2010). Schumpeter Meeting Keynes: A Policy-Friendly Model of Endogenous Growth and Business Cycles. *Journal of Economic Dynamics and Control*, 34(9):1748–1767.

Dosi, G., Roventini, A., and Russo, A. (2017). Endogenous growth and global divergence in a multi-country agent-based model. *LEM Working Paper Series*, 2017/32:34.

Economides, A., Philippopoulos, A., and Varthalitis, P. (2016). Monetary union, even higher integration, or back to national currencies? *CESifo Economic Studies*, 62(2):232–255.

European Commission (2022). Communication on orientations for a reform of the eu economic governance framework, n.583.

Eyraud, L., Gaspar, V., and Poghosyan, T. (2017). Fiscal politics in the euro area. *IMF Working Paper Series*, 17-18:44.

Fagiolo, G. and Roventini, A. (2016). Macroeconomic policy in dsge and agent-based models redux: New developments and challenges ahead. *Journal of Artificial Societies and Social Simulation Redux*, 20(1):37.

Farhi, E. and Werning, I. (2017). Fiscal unions. *American Economic Review*, 107(12):3788–3834.

Gerali, A., Neri, S., Sessa, L., and Signoretti, F. (2010). Credit and banking in a dsge model of the euro area. *Journal of Money, Credit and Banking*, 42:107–141.

Godley, W. and Lavoie, M. (2007). Fiscal Policy in a Stock-Flow Consistent (SFC) Model. *Journal of Post Keynesian Economics*, 30(1).

Gootjes, B. and de Haan, J. (2022). Procyclicality of fiscal policy in european union countries. *Journal of International Money and Financ*, 120:29.

Gräbner-Radkowitsch, C., Heimberger, P., Kapeller, J., Landesman, M., and Schütz, B. (2022). The evolution of debtor-creditor relationships within a monetary union: Trade imbalances, excess reserves and economic policy. *Structural Change and economic Dynamics*, 62:262–289.

Gualdi, S., Tarzia, M., Zamponi, F., and Bouchaud, J. (2015). Tipping points in macroeconomic agent-based models. *Journal of Economic Dynamics & Control*, 50:29–61.

Holcombe, M., Coakley, S., Kiran, M., Chin, S., Greenough, C., Worth, D., Cincotti, S., Raberto, M., Teglio, A., Deissenberg, C., van der Hoog, S., Dawid, H., Gemkow, S., Harting, P., and Neugart, M. (2013). Large-scale modeling of economic systems. *Complex Systems*, 22:175–191.

Howarth, D. and Schild, J. (2021). Nein to 'transfer union': the german brake on theconstruction of a european union fiscal capacity. *Journal of European Integration*, 43(2):209–226.

Kenen, P. (1969). The theory of optimum currency areas: An eclectic view. In Mundell, R. and Swoboda, A., editors, *Monetary Problems of the International Economy*. Chicago: University of Chicago Press.

Ladi, S. and Tsarouhas, D. (2020). Eu economic governance and covid-19: policy learning and windows of opportunity. *Journal of European Integration*, 42-8:1041–1056.

Lavoie, M. (1992). *Foundations of Post-Keynesian Economic Analysis*. Edward Elgar, Aldershot.

Lorentz, A., Ciarli, T., Savona, M., and Valente, M. (2016). The effect of demand-driven structural transformations on growth and technological change. *Journal of Evolutionary Economics*, 26:219–246.

Meyers, S. (1984). Capital Structure Puzzle. *Journal of Finance*, 39-3:575–592.

Monnet, J. (1978). *Memoirs*. Doubleday Publishers, New York.

Mundell, R. A. (1961). A theory of optimum currency areas. *American Economic Review*, 51(4):657–665.

Nelson, R. and Winter, S. (1977a). Simulation of Schumpeterian Competition. *The American Economic Review*, 67-1:271–276.

Nelson, R. and Winter, S. G. (1977b). Simulation of Schumpeterian Competition. *The American Economic Review*, 67-1:271–276.

Nelson, R. and Winter, S. G. (1982). *An Evolutionary Theory of Economic Change*. Harvard University Press, Cambridge MA., Cambridge, MA.

Petrovic, M., Ozel, B., Teglio, A., Raberto, M., and Cincotti, S. (2017). Eurace open: An agent-based multi-country model. *Working Paper Series of the Economics Department of the Universitat Jaume I, Castellon (Spain)*, 2017-09:76.

Petrovic, M., Ozel, B., Teglio, A., Raberto, M., and Cincotti, S. (2020). Should i stay or should i go? an agent-based setup for a trading and monetary union. *Journal of Economic Dynamics & Control*, 113.

Rengs, B. and Wäckerle, M. (2014). A computational agent-based simulation of an artificial monetary union for dynamic comparative institutional analysis. In *Proceedings of the 2014 IEEE Conference on Computational Intelligence for Financial Engineering & Economics (CIFEr)*, pages 427–434.

Riccetti, L., Russo, A., and Gallegati, M. (2015). An agent-based decentralized matching macroeconomic model. *Journal of Economic Interaction and Coordination*, 10-2:305–332.

Russo, A., Riccetti, L., and Gallegati, M. (2016). Increasing inequality, consumer credit and

financial fragility in an agent based macroeconomic model. *Journal of Evolutionary Economics*, 26(1):25–47.

S., P., Miess, M., Hommes, C., and Rabitsch, K. (2022). Economic forecasting with an agent-based model. *European Economic Review*, 151.

Salop, S. C. (1979). Monopolistic competition with outside goods. *The Bell Journal of Economics*, 10-1:141–156.

Smets, F. and Wouters, R. (2007). Shocks and frictions in us business cycles: A bayesian dsge approach. *American Economic Review*, 97:586–606.

Steindl, J. (1952). *Maturity and Stagnation in American Capitalism*. Blackwell.

Taylor, J. B. (1993). Discretion versus policy rules in practice. *Carnegie-Rochester Conference Series on Public Policy*, 39-1:195–214.

Wolf, S., Furst, S.and Mandel, A., Lass, W., Lincke, D., Pablo-Marti, F., and Jaeger, C. (2013). A multi-agent model of several economic regions. *Environmental Modelling & Software*, 44:25–43.

Woo, J. (2009). Why do more polarized countries run more procyclical fiscal policy? *The Review of Economics and Statistics*, 91(4):850–870.

Zezza, G. (2012). The impact of fiscal austerity in the euro zone. *Review of Keynesian Economics*, 1:37–54.

A Baseline Setup

Table 1: Parameters

K: Number of countries	5	μ_2: Minimal reserve requirement parameter	0.01
H: Number of Households	500	ι_l: Loan probability parameter	2.5
l^S: Workers' labor supply	1.0	χ: Loan interest parameter	0.005
ψ: Matching parameter	10	ι_b: Bond probability parameter	0.1
υ: Wage revision probability parameter	1.625	r_{re}: Interest paid on banks' reserves	0.0
υ_H: Wage revision probability households	0.7	r_{b0}: Initial interest on bonds	0.001
υ_F: Wage revision probability firms	1.0	w_0: Initial wage	1.0
ϕ_0: Initial productivity	1.0	$\bar{r}$: Taylor rule long run interest rate	0.0075
τ_0: Initial tax rate	0.45	ξ: Taylor rule adjustment speed parameter	0.8
c_y: Propensity to consume out of income	0.8	$\xi^{\Delta P}$: Taylor rule sensitivity to inflation	2
c_D: Propensity to consume out of wealth	0.05	$\overline{\Delta P}$: Inflation Target	0.005
δ: Adaptive Parameter	0.04	d^{max}: Maximum deficit-GDP ratio	0.03
c_T: Share of tradable	0.4	tau_{min}: Minimum tax rate	0.4
β: Hotelling circle parameter	2.0	tau_{max}: Maximum tax rate	0.5
λ: Liquidity preference parameter	0.1	g_{min}: Minimum G/GDP	0.4
θ: Share of sales as inventories	0.1	g_{max}: Maximum G/GDP	0.5
γ: R&D expenditure parameter	0.03	η: Banks-firms minimum proportion	0.1
ν: R&D success probability parameter	0.8	ϖ: Minimum investment threshold parameter	0.1
ρ: Share of profits distributed	0.95	A^0: First firms' initial net worth	10.0
ζ: Deposit interest-discount rate ratio	0.1	σ: Banks' minimum dimension relative to firms	4
μ_1: Total credit supply parameter	30	G: Initial real value of public spending	225
δ_G: Government/Union Adaptive Parameter	0.02	d_U^*: Union target deficit-GDP ratio	0.03

B Robustness check with a varying number of countries

In order to check the robustness of the results discussed in Section 4, we plot the results obtained by changing the number of countries involved in the simulations, and hence the dimension of the Union, from the simplest 2-country case to the 8-country case, assuming national contributions of 1% of GDP, i.e., $\alpha = 0.01$.

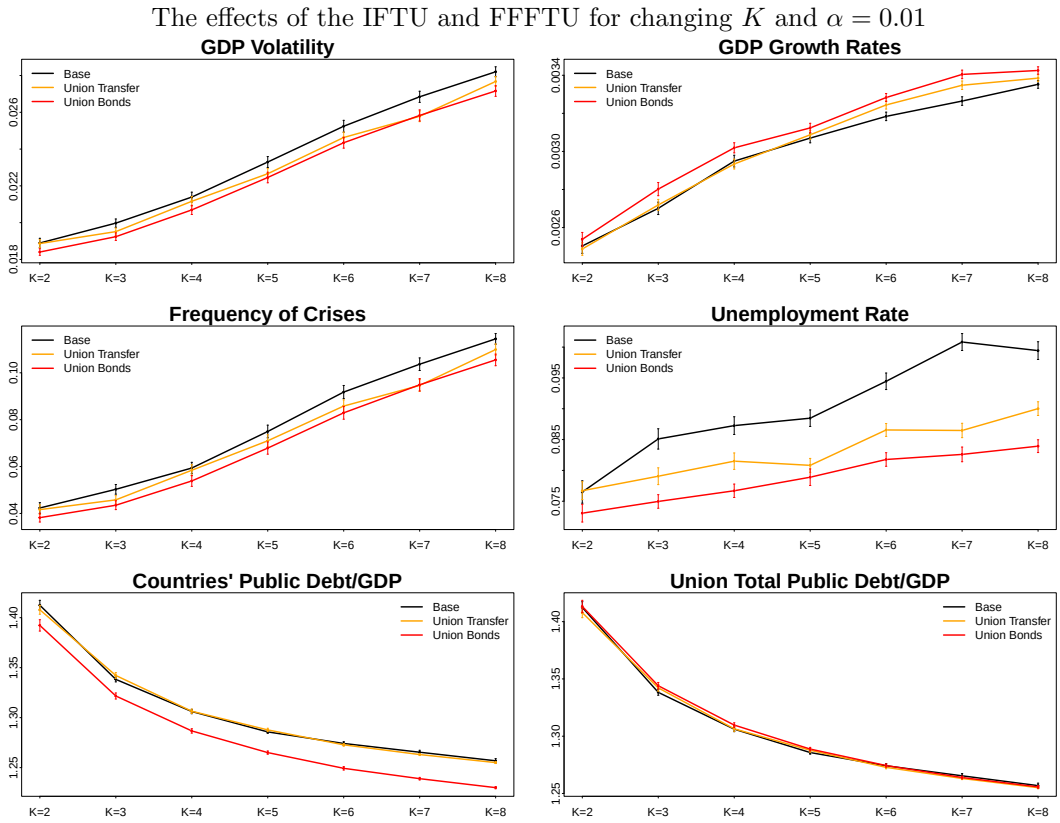

Figure 8: Points represent Monte Carlo averages of the displayed variables and bars are standard deviations across Monte Carlo repetitions. Black lines refer to the baseline scenario, i.e $\alpha = 0$. The yellow and red lines refer, respectively, to the IFTU and FFFTU cases assuming national contributions to the Union budget equal to $\alpha = 0.01$ of GDP. The horizontal axis shows the number of countries employed in each battery of simulations. From the top-left: countries' average standard deviation of real GDP, countries' average real GDP growth rates, countries' average frequency of occurrence of a major crisis (arbitrarily defined as a contraction of real GDP greater than 3%), countries' average unemployment rate, countries' average public debt-to-GDP levels, and finally, the total debt-to-Union GDP level.

Overall, the beneficial effects of the two new institutional settings in terms of GDP stabilization, GDP growth, and unemployment are confirmed, particularly for the FFFTU. However, in a few cases, the difference of an IFTU with the baseline is not statistically significant (e.g., for GDP growth rates in the K=2,3,4,5 cases). This seems to occur, in particular, when the number of countries is lower, and it might well be explained by the fact that when the number of

countries decreases, the dimension of the common market for tradables also decreases relative to domestic economies, and so does the importance of international spillovers through foreign trade in driving economic growth of member countries.[18] Since both the IFTU and FFFTU mainly exert their effects by operating on this foreign channel, a smaller Union may reduce their scope, though the FFFTU still proves able to make a statistically significant difference with respect to the baseline thanks to the greater fiscal space and flexibility provided by the issuance of common debt that makes the expenditure of the Union less sensitive to the cyclicality of the national contributions financed through taxes.

Finally, the results concerning the overall negligibility of the effects exerted by these two institutional architectures on the amount of public debt seem to be confirmed.

[18]The relevance of such an aspect for the dynamics displayed by the model has already been discussed in Caiani et al. (2018a) and Caiani et al. (2019).