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The effects of alternative wage regimes in a monetary union: A multi-country agent based-stock flow consistent model

Alessandro Caiani[a,*], Ermanno Catullo[b], Mauro Gallegati[b]

[a] University of Pavia, Italy
[b] Marche Polytechnic University, Italy

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ABSTRACT

The Eurozone crisis has revitalized the debate between economists on the role played by wages in open economies. Salaries paid to workers are at the same time a fundamental source of aggregate demand and a determinant of firms' international cost competitiveness. The paper investigates how alternative wage growth patterns impact on the economic dynamics of an artificial Monetary Union. For this sake, we perform several experiments employing the Agent Based-Stock Flow Consistent (AB-SFC) Multi-Country model first presented in Caiani et al. (2018a).

Results show that a change in the wage growth pattern impacts in non-trivial ways on the demand and supply sides of the economies, giving rise to Keynesian and Schumpeterian effects. When occurring in a single country, wage expansions lead to a transitory deterioration of the country current account and to a slow-down of the economy in the short-run. However, on a longer time-span, higher wages tend to improve firms' innovative performance by strengthening the process of Schumpeterian competition, providing long-run benefits in terms of higher labor productivity which allow the economy to recover. Conversely, a coordinated expansion of wages in all countries, which leaves their relative competitive position unaffected, tends to benefit real GDP, labor productivity growth, and countries' public finance, while not affecting unemployment and countries' external balance. A specular dynamics characterizes the experiments investigating the effects of wage moderation.

Extensive sensitivity experiments show that these results are robust to different dimensions of the Monetary Union and that the efficacy of coordinated wage expansionary strategies is enhanced when consumers give more importance to price differentials in their consumption allocation decisions.

1. Introduction

The paper builds on Caiani et al. (2018a) in presenting an Agent Based-Stock Flow Consistent (AB-SFC) Multi-Country model to analyze the impact of alternative wage growth patterns in a Monetary Union broadly comparable to the European Economic and Monetary Union (EMU).[1]

* Corresponding author.
E-mail address: alessandro.caiani@unipv.it (A. Caiani).

[1] The model has been developed using Python. Results have been analyzed using the R statistical environment. The codes of the model are freely available upon request.

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The Eurozone sovereign debt crisis broke out in May 2010, three years after the global financial turmoil, and still many doubts remain about whether the recent positive outlooks can represent a turning point and the start of an enduring recovery. In many countries unemployment, in particular for the youngest, is still at unprecedented levels and the GDP is far from its pre-crisis levels. Concerns about the state of the public finance and the resilience of the financial sector are widespread. In the meanwhile, the economic malaise has favored the rise of populism with nationalistic and xenophobic tendencies across European countries. Despite the exceptional and unprecedented policy interventions launched to preserve the Euro, the European institutional architecture has revealed its inherent flaws and it is now widely recognized that many of the policy responses implemented in the aftermath of the euro-crisis were ill-designed to face the centrifugal forces that threatened the Union, if not contributing to feed them.[2]

In 2015 a dozen of leading economists with different backgrounds made an attempt to construct a 'consensus' narrative of the Eurozone crisis (Baldwin et al., 2015). They pointed out that this should not be regarded as a sovereign debt crisis in its origin, arguing that the real culprits were the large capital flows that emerged in the decade before the crisis from Eurozone core economies like Germany, France, and the Netherlands to Eurozone periphery nations like Ireland, Portugal, Spain, Greece and, to a lesser extent, Italy. As a major share of these capital inflows were invested in non-traded sectors, typically housing and public consumption, no assets were created to pay off the borrowing. Furthermore, foreign-financed domestic spending tended to drive up wages and costs in a way that harmed the competitiveness of the receivers' exports and encouraged a further worsening of their current accounts. When the global financial turmoil hit Europe, there was a sudden stop in cross-border lending which triggered the Eurozone crisis.

However, the 'policy' consensus view put forward within European institutions diverged from this 'academic' consensus interpretation under several respects. On the one hand, in contrast with Baldwin et al. (2015), the European narrative insisted on the alleged fiscal profligacy of peripheral countries, considered as the fundamental jeopardizing factor of the system. On the other hand, they agreed on contending the existence of a labor-cost competitiveness issue affecting Southern Europe, leading to unsustainable trade imbalances and amplified by the flow of cheap credit from core to peripheral countries. Strong fiscal consolidation programs were then imposed on countries in trouble, accompanied by a generalized tightening of fiscal austerity rules for all European countries. Structural reforms aiming to restore cost competitiveness through good and labor markets deregulation were implemented in many countries, feeding the wage deflation process already ongoing (Jaumotte and Sodsriwiboon, 2010). These policy prescriptions were then formalized in the provisions of the *Stability and Growth Pact*, the *Fiscal Compact*, and the *Competitiveness Pact-Euro Plus Pact*.

Caiani et al. (2018a) aimed to put to test the rationale behind the adoption of tight fiscal rules common to all member countries, as provided by the *Stability and Growth Pact*, by analyzing in an extensive way the effects of alternative fiscal regimes within the artificial Monetary Union depicted by our Agent Based-Stock Flow Consistent (AB-SFC) Multi-Country model.

The present work instead focuses on the second pillar of the 'policy' consensus view put forward by European institutions, by exploring the twofold role of wages as a source of aggregate demand and as a determinant of countries' international competitiveness. For this sake, we employ the model to compare the effects of isolated changes in the growth pattern of wages occurring in single countries, as well as of coordinated changes occurring in all Union countries at the same time.

Results show that changes in the wage growth pattern affect the dynamics of both demand and supply in non-trivial ways: by strengthening or lessening the pressure of wages on firms' profit margins they influence the evolutionary selection of firms by affecting the probability of survival of less productive firms. Wage inflationary scenarios tend to foster a transition towards a more concentrated market structure characterized by fewer and bigger firms which favors a better allocation of R&D investment: in line with what is usually labeled as a 'Schumpeter Mark II' innovative regime, big firms invest more in R&D and thus have better chances to succeed. Vice-versa, wage moderation regimes lead to a more fragmented market structure where R&D investment is split between many small producers, thereby reducing its efficacy. These regimes thus tend to hinder the dynamics of innovation, resulting in a slower productivity dynamics.

Initial experiments highlight that changes in the wage growth regime of individual countries are characterized by a trade-off between their external and fiscal stance on the one hand, and the dynamics of real GDP and labor productivity on the other. In fact, wage expansions lead to a transitory deterioration of the country current account which worsens its net foreign asset position and causes real GDP to slow-down in the short run. As a consequence, also public debt-GDP ratios tend to rise. However, in the long run wage expansionary scenarios enhance labor productivity growth, allowing real GDP to recover and possibly to outperform other countries. This allows to absorb current account imbalances stabilizing the net foreign asset position of the country and public debt-GDP levels, though the higher labor productivity attained exerts a labor saving effect, slightly increasing unemployment levels. An almost specular dynamics emerges when a country purses a wage moderation strategy in isolation. If we look at the global effects on the whole Union, however, we notice that wage expansions in a single country slightly improve the Union global performance, whereas the specular wage moderation case tends to dampen it.

When, instead, the change in the growth pattern of wages occurs simultaneously in all member countries, as a result of a coordinated strategy, their relative competitive position is left unaltered, so that their external stance is no longer

[2] An interesting compendium of interventions by leading economic scholars in this economic and political debate on the Eurozone challenges can be found in Baldwin's (2015) review of the columns appeared on *VoxEU*, and in the *VoxEU* Debate section 'Euro Area Reform'.

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affected: results show that a coordinated wage inflationary strategy spurs real GDP growth, innovation dynamics, and labor productivity growth, while also benefiting public finance by reducing average public debt/GDP levels. Employment levels in this scenario are instead almost unaffected, as the rise of real aggregate demand allows to offset the possible labor-saving effect due to the stronger innovation dynamics. The effects of a coordinated wage moderation strategy are almost symmetric.

As a robustness check we re-execute the experiments on the coordinated wage growth strategies by changing the dimension of the Monetary Union relatively to national economies, that is, by modifying the number of countries involved in the simulations. Results are robust under the specifications tested.

Finally, we perform a further sensitivity analysis to check the impact of coordinated changes in the wage growth patterns when consumer demand is more or less sensitive to price differentials. Results show that the effects previously highlighted for the coordinated wage expansionary and wage moderation regimes are reinforced when the allocation of consumer demand over different producers is more sensitive to their price differentials.

In the next subsection (1.1) we present an overview of the main interpretations provided to explain the Euro crisis, with particular reference to the dynamics of wages across Eurozone countries and their role in determining demand and trade patterns. The policy implications of these alternative and often conflicting explanations are also discussed. Section 2 presents the model and provide a synthetic explanation of the initialization and validation procedures employed. Section 3 explains the experiment design employed to test the effect of alternative wage growth patterns, and then discusses the results of the simulation experiments performed. Finally, Section 4 concludes with a summary of the main results and a brief discussion of current limitations and possible future refinements of the model.

1.1. Conflicting views on the causes and remedies of Eurozone imbalances

The structural reforms advocated by European policy makers found a theoretical support in the work of Neoclassical scholars. According to Sinn (2014a,b) for example, over-regulated labor markets, strong unions and excessive labor protection in peripheral countries caused wages to grow faster than productivity. The consequent rise of unit labor costs caused export growth to fall and import growth to rise, generating persistent and growing current account deficits in the periphery, mirrored by rising trade surplus at the core, in particular by Germany. The funding of peripheral countries' trade deficit required capital to flow in the opposite direction, in the form of credit granted by core countries to the private and public sectors of the periphery, so that countries in surplus also experienced an equal increase of their net foreign lending position vis-à-vis other European countries (Lane, 2013). Chen et al. (2012) and Unger (2017) integrate this interpretation pointing to the process of international financial integration realized through the common currency. Coupled with over-optimistic expectations of convergence[3], this caused a decline in the credit constraints and real interest rates for periphery countries, leading to persiste increases in domestic prices and unit labor costs eventually resulting in a real exchange rate appreciation which crowded out manufacturing and export activities. According to the Neoclassical consensus view, Southern countries have lived beyond their means thanks to the flow of cheap credit coming from Northern countries: the rise of unemployment, the fall of aggregate demand, and the wage deflation process observed in peripheral countries should then be interpreted as a necessary re-equilibrating process required to absorb international trade imbalances (Blanchard, 2007). In a policy perspective, this explanation prescribes that efforts should be mainly dedicated to restore competitiveness in Southern countries by dampening wage growth (Jaumotte and Sodsriwiboon, 2010) through labor market deregulation aiming to "review the wage setting arrangements, and, where necessary, the degree of centralization in the bargaining process" (General Secretariat of the European Council, 2011, p.17). Labor and product market deregulation, aiming to restore cost competitiveness, have become an almost ubiquitous prescription within European Institutions (Juncker et al., 2015).

However, many recent works have criticized the empirical and theoretical ground of the 'Necolassical' explanation of the Eurozone crisis. Hall (2012), for example, insists on the disproportionate imposition of the costs of the adjustment between core (lender) and periphery (borrower) countries and contends that export-led growth strategies commonly advocated for Southern countries were not practicable in the institutional framework of the Union, where Southern countries lost their capacity to devalue. From his column on the *New York Times*, the Nobel Prize Paul Krugman has long warned against the costs of the wage deflation process triggered by austerity measures in peripheral countries, that he considered doomed to failure unless coupled by expansionary policies at the core.

A more critical stance is taken by Flassbeck and Lapavitsas (2013). In their view, trade European imbalances were not the result of the excessive wage growth in the periphery, nor of their alleged fiscal profligacy, but rather the consequence of Germany's 'beggar thy neighbor' policy realized by squeezing workers' wages. A similar interpretation is provided by Stockhammer (2011) and Stockhammer et al. (2016) who point to the combination of an export-led growth strategy in the North faced by a credit-led strategy fed by capital inflows in the South to explain Eurozone imbalances. Onaran and Galanis (2012); Onaran and Obst (2016); Stockhammer et al. (2009); Stockhammer and Sotiropoulos (2014) show that wage moderation may work for small individual countries but, when generalized, it is likely the recipe for stagnation, in particular within a highly integrated global economy, since it neglects the role of wages in the demand formation. The evidence

[3] See in particular the strand of literature originating from the seminal contribution of Frankel and Rose (1997, 1998): these authors argue that, since countries with closer trade links tend to have more tightly correlated business cycles, the criteria for an Optimal Currency Area tend to be more easily satisfied after taking steps toward economic integration than before. For a comprehensive review of the literature on the endogenous effects of monetary integration, see De Grauwe and Mongelli (2005).

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provided by this literature on wage-led growth regimes in Europe is consistent with some of the key insights gained from our simulation experiments, as we comment in Sections 3.2, 3.3, and 3.4.

Other studies, instead, have questioned the very relevance of wages and unit labor costs in driving international trade flows. Christodoulopoulou and Tkacevs (2016), for example, find that exports of goods and services of Euro countries are either insensitive to changes in price and cost competitiveness, or their sensitivity is lower than usually thought, suggesting that non-price competition factors have an important role in explaining exports developments in several Eurozone countries. Diaz Sanchez and Varoudakis (2013) and Gabrisch and Staehr (2014) arrive to similar conclusions using, respectively, a panel-data vector autoregressive model and Granger causality tests. Given the low marginal effect of labor costs on export dynamics, attempts to restore international competitiveness through retrenchment of labor costs would require to be so harsh to be economically and politically unfeasible.

On a similar ground Storm and Naastepad (2015a,b) argue that the deflationary adjustments forced on Southern Europe are not only ineffective in absorbing trade imbalances, but also likely to damage their productive base exacerbating productivity differentials between surplus and deficit countries. These works stress the impact of wages and demand on firms' innovative performance and labor productivity dynamics: Storm and Naastepad (2012) for example, show that higher employment protection and more extensive labor market regulation are associated with higher labor productivity growth whereas unregulated markets, weak employment protection, low taxes, high earnings inequalities, and weak unions are detrimental to technological dynamism. A similar conclusion is reached by Kleinknecht (1998); Kleinknecht et al. (2014); Vergeer and Kleinknecht (2014) who stress the role played by wages in shaping the Schumpeterian competition process. The same mechanism seems to operates also in our model, as we comment in Section 3.2.

Another criticism against the Neoclassical interpretation comes from those who point to capital, rather than trade, flows to explain the origin of Eurozone current account imbalances, thereby stressing, in a policy perspective, the importance of monitoring the dynamics of credit within and across countries. Gaulier and Vicard (2012), for example, argues that inflows of foreign capital to the non-tradable sectors of peripheral countries boosted the demand for imports and fueled increases in prices of goods and services, in particular non-tradable goods and services, such as constructions. The emergence of a gap between unit labor costs in peripheral countries and Germany would then be the "signature" of a demand shock affecting domestic non-tradable sectors, rather than of a competitiveness shock affecting the tradable sector. Comunale and Hessel (2014) show that the differences in the export performance of European countries are largely dependent on the composition of their exports, and that differences in domestic demand driven by the financial cycle are a fundamental driver of trade imbalances in the Eurozone. Finally, Hobza and Zeugner (2014) show that core countries played a dominant role in financing the periphery's current account deficits before the financial crisis, both directly and through intermediating financial flows from outside of the Euro area.

2. Model description

The paper aims at investigating how changes in the growth patterns of wages affect the economic relationships between countries belonging to a Monetary Union and their economic performance. For this sake, we employ the Agent Based-Stock Flow Consistent multi-country model first presented in Caiani et al. (2018a) which aims to represent an artificial Monetary Union similar to the EMU. Obviously, the model is simplified under many respects compared to the complexity of economic systems observed in reality and cannot account for many important historical and country-specific factors. In particular, the financial side is still over-simplified. Our analysis thus focuses more on trade-related factors than on financial ones. Nonetheless, we believe the model provides an exhaustive framework to analyze both the 'static' effects of wages on demand and international price competitiveness, and the 'dynamic' effects on markets evolution, R&D, and technological progress.

Using computer simulation, we can test counter-factual or hypothetical scenarios in a controlled-environment. This is an important feature which makes computational models a useful complementary tool to standard econometric and statistical analysis. In order to investigate the role of wages as a source of domestic demand and as a cost factor affecting countries' international competitiveness we carry out several different experiments: first, we analyze the effects of slowdowns or accelerations of wages growth in a single randomly sampled country. Second, we consider the case of a coordinated change in the wage growth regime agreed by all countries. Then, we perform and extensive sensitivity to check if and how the dimension of the Union and of its common market for tradables affect the results of these experiments. Finally, we investigate the effect of alternative wage strategies when price competitiveness becomes less or more important for consumers' choices, by modifying the elasticity of consumers' final demand to prices.

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 ($I_{k,t}$) and banks ($Z_{k,t}$), depending on defaults arising endogenously during the simulation and on households' equity investment in the creation of new firms and banks.

Fig. 1 provides a graphical representation of the structure of each national economy, and of its trade and financial relationships with the other countries of the Union.

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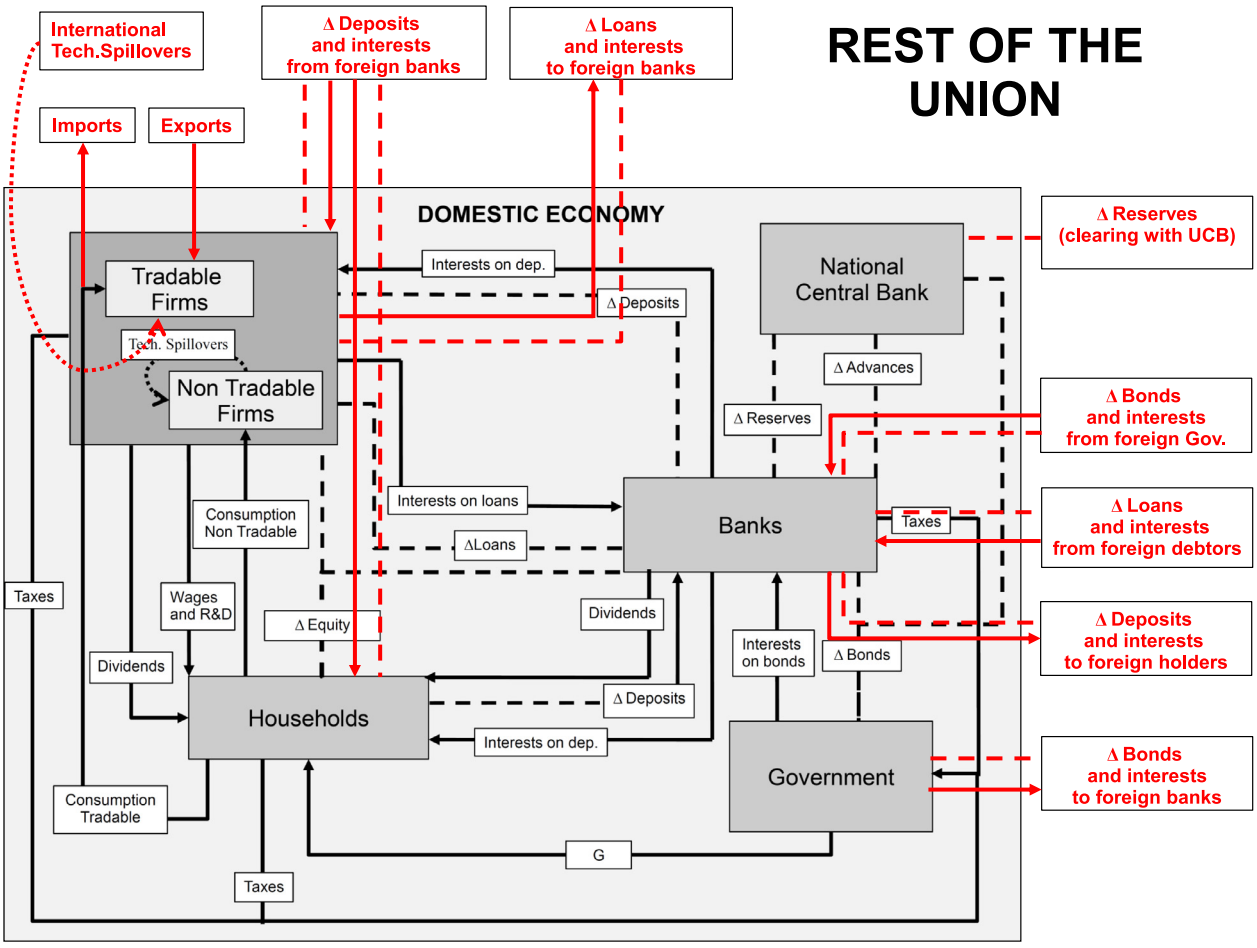

Fig. 1. Flow Diagram of a national economy versus the rest of the Union. Arrows point from paying sectors to receiving sectors. Dashed lines are variation of stocks caused by flows of funds originated during each period. Dotted lines are used to represent domestic technological spillovers in the non-tradable sector and international technological spillovers in the tradable sector originating from firms' imitation activity.

The model considers a 'pure labor' economy *à la* Adam Smith[4] where production by firms is carried out using labor only, with no machineries. Firms are subdivided into tradable and non-tradable: the former produce goods which are traded on the common market, while the latter sell their output on the domestic market for non-tradables.

International transactions involve transfers of goods, deposits, and bank reserves. Firms can demand credit to both domestic and foreign banks. The bond market, where bonds issued by member countries can be purchased by commercial banks, is internationally integrated. For simplicity reasons, labor cannot move across countries and households are allowed to invest only in the equity of domestic (tradable and non-tradable) 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.

The Union Central Bank set the policy rate (i.e. the interest paid on cash advances demanded by commercial banks to fulfill mandatory liquidity constraints). National Central Banks accommodate commercial banks' demand for cash advances and buy the possible residual traches of bonds issued by their country's government which have not been purchased by private banks.

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

Following the logic of Caiani et al. (2016, 2018b, 2018c); Riccetti et al. (2015, 2016) the model dynamics is driven by agents' adaptive reactions and decentralized interactions through specific matching protocols on the various markets mod-

[4] See also the book by Pasinetti (1993) presenting a simple model of a 'pure labor' economy, in which many goods are produced by labor alone.

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eled. 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 Agent Based macroeconomic literature dealing with open economies is still relatively narrow. The EURACE-Unibi model employed in Dawid et al. (2012, 2014, 2018a, 2018b); Deissenberg et al. (2008), probably one of the most sophisticated in the literature, has been extensively employed to test a variety of issues related to the functioning an regulation of an economic Union. Cardaci and Saraceno (2017) analyze the role of inequality in determining diverging balance of payments dynamics within a currency union. However, these works rely on a two-region framework. Our model (Caiani et al., 2018a) instead considers multiple countries. To our knowledge, there are only a few examples of models than can be initialized with a variable number of countries: the multi-country extension of the LAGOM model presented in Wolf et al. (2013); the evolutionary model of an artificial monetary Union first presented in Rengs and Wäckerle (2014) and later employed, though in a simplified two-country setup, in Rengs and Scholz-Wäckerle (2017); the open version of the Eurace model (Deissenberg et al., 2008) presented in Petrovic et al. (2017); the multi-country model presented in Dosi et al. (2017), inspired by the 'Schumpeter+Keynes' family of models descending from Dosi et al. (2010).

The use of a multi-country framework has several advantages: first, it allows to test scenarios where individual countries represent a significant share of the Union, thereby being able to affect its overall dynamics with their decisions, as well as scenarios in which countries are small compared to the Union, and thus barely able to exert, individually, a significant impact on the rest of the Union. In addition, considering multiple countries provides a better-suited framework to analyze phenomena which can hardly be simplified to a 'closed economy' or to a 'core vs periphery' scheme such as, for example, the spreading of financial contagion across banks and investors in different countries. Finally, we believe providing a multi-country framework presents several advantages in terms of realism and variety of scenarios that can be tested.[5]

Other important novelty aspects encompassed by the model are: the adoption of a Stock Flow Consistent framework (Godley and Lavoie, 2007) so to provide a rigorous, comprehensive, and fully integrated representation of the real and financial sides of the economy; the endogenization of the entry-exit process of firms and banks based on a stylized mechanism to model households' equity investment; the adoption of an intuitive "generative" procedure to initialize the model in a Stock Flow Consistent manner; the adoption of a locational model inspired by Salop's (1979) circular specification of Hotelling (1929) to differentiate consumers' preferences and firms' products.[6]

Next subsections sketch out in a synthetic way the behaviors of agents and the structure of their interactions on the different markets.

2.1. Agents

2.1.1. Households

Households play three main roles in the model: they are workers, equity holders, and consumers.

On the labor market workers interact with ψ randomly sampled potential employers trying to sell them their labor force l^S, which is normalized to 1. The quantity of labor sold to firms $l_{h,t}$ is then equal to 1 if the worker is fully employed, $0 < l_{h,t} < 1$ if the worker is part-time employed[7], and finally $l_{h,t} = 0$ if the worker is unemployed. Workers can sell their unitary labor supply to different employers until they have exhausted it. As a consequence, they can be employed by different employers at the same time. We define $l_{hi,t}$ as the quantity of labor sold by worker h to firm i, and $w_{hi,\,t}$ the wage he receives in exchange for it. The total labor sold by the household h in period t is then: $l_{h,t} = \sum_{i,l_{hi,t}>0}^{l_{k,t}} l_{hi,t}$.

Workers choose the employer offering the highest wage but they do not accept vacant positions below a reservation level $w_{h,t}$ which is adaptively revised from period to period depending on the worker's past employment condition and on the aggregate level of unemployment according to Eq. (1). Workers who are not fully employed tend to decrease their reservation wage, while full-time workers tend to increase it. The probability of such a revision, however, depends on the aggregate level of unemployment: upward revisions are more likely to occur when unemployment is low while downward revisions are more likely if unemployment is high. The two probabilities stand in the following relationship: $Pr(w^+_{h,t}) = 1 - Pr(w^-_{h,t})$. This stochastic mechanism proxies the idea that workers' wage claims are negatively affected by higher levels of unemployment, with the parameter $\upsilon > 0$ shaping the strength of this relationship.[8]

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

To employ a parsimonious notation, we indicates throughout the paper by $U[x_1, x_1]$ the realization of a stochastic variable distributed according to a Uniform defined between x_1 and x_2, rather than the distribution itself. Therefore, $U[0, \delta]$ indicates

[5] For example, it might allow to employ more realistic initial conditions where countries are differentiated for their dimension, productivity, income, and public and private debt levels.

[6] For a more detailed discussion of these and other methodological and modeling aspects see Caiani et al. (2018a).

[7] Firms' labor demand in fact is formulated as a positive real number so that for each firm there will be a 'marginal' worker employed only for the decimal part. Another reason why $l_{h,t}$ can be between 0 and 1 is the presence of financial constraints which may prevent the firm from employing the worker at full time.

[8] Given the importance of this aspect for the design of the experiments performed in the paper, we further discuss it in Section 3.1.

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a random sample from a Uniform distribution defined between 0 and δ. The parameter υ_H represents a scaling factor, whose value is calibrated in relation to the corresponding scaling parameter υ_F for firms' offered wage revision rule (Eq. (15) in Section 2.1.2) in order to avoid having an excessive mismatch between the wages offered by firms and the reservation wages of workers which would give rise to unreasonable levels of 'frictional' or 'voluntary' unemployment: the agent-specific condition which induces firms to consider the possibility of rising wages (i.e. firm's inability to fill all vacant positions) is in fact inevitably less frequent than the corresponding agent-specific condition inducing workers' to consider rising their reservation wage (i.e. having been fully employed in the last period). Imposing $\upsilon_H < \upsilon_F$ is then required to avoid workers' reservation wages to rise too fast compared to firms' offers.[9]

Workers can be employed by firms for production and R&D activities indifferently. Investment in Research and Development activities ($R\&D_{i,t}$, see Section 2.1.2) is thus assumed to add on to workers' labor income, being distributed according to the quantity of labor they individually supply.

In addition, households also receive interests on deposits $D_{h,t}$ from banks, dividends from participated firms and banks ($Div_{h,\,t}$), and a tax-exempt monetary transfer ($G_{k,t}/H$) from the government of their country k.

Defining by $\tau_{k,t}$ the tax rate charged by the government, households' gross and net income (respectively $y_{h,t}$ and $y^D_{h,t}$, where D stands for 'disposable') can be expressed as:

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

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

Households' desired nominal consumption ($C^D_{i,t}$) is a linear function of current disposable income and current wealth held in the form of deposits, with fixed marginal propensities c_y and c_d:[10]

$$C^D_{h,t} = c_y y^D_{h,t} + c_d D_{h,t} \tag{4}$$

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

$$C^{DT}_{h,t} = c_T C^D_{h,t} \tag{5}$$

$$C^{DNT}_{h,t} = (1 - c_T) C^D_{h,t} \tag{6}$$

On the tradable and non-tradable markets consumers samples ψ potential suppliers and rank them from the most to the least preferred. The model employs a locational specification of consumers' preferences and firms' offered varieties inspired by Salop's (1979) circular refinement of Hotelling (1929): we assume that good varieties produced by firms' and consumers' preferences are randomly located on a circle with unitary diameter. We define d_{hi} as the distance between consumer h and a firm i.[11]

Consumers ranks suppliers based on their distance and their offered price: the lower the price and the distance of a given supplier, the greater the satisfaction that the consumer gets from consuming its products (i.e. the greater the preference for the supplier). Formally, household h prefers firm i to firm j if:

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

where $p_{i,t}$ and $p_{j,t}$ are the prices charged by the two suppliers, P_t is the sector average price, and $\beta \geq 0$ is a parameter weighting households' preferences for variety: the lower β, the more consumers perceive consumption goods as homogeneous, their consumption allocation becoming more sensitive to price differentials.[12]

[9] For the sake of clarity, it must be noticed that this heuristics has been refined with respect to the simpler version presented in Caiani et al. (2018a) in two fundamental respects: first, while in the former version only upward revisions were assumed to occur with a probability depending on unemployment levels, whereas downward revisions occurred with certainty whenever $l_{h,t-1} < 1$, here both types of revisions depend on a probabilistic term, defined as a function of u. Secondly, we added the scaling factor within these probability functions υ_H.

[10] The adoption of a linear function with fixed propensities is very common in the SFC literature in the wake of Godley and Lavoie (2007), as well as in the AB literature: for example, Ashraf et al. (2016); Assenza et al. (2015); Dawid et al. (2018a); Dosi et al. (2010); Riccetti et al. (2015); Seppecher (2012), all employ a similar type of linear function, though providing different theoretical and empirical backgrounds. The main drawback of this simple specification is that it does not allow to analyze the impact of the personal income and wealth distribution on demand patterns. However, this is beyond the objective of this paper which focuses on wage differentials across countries, rather than within countries.

[11] Being ω_i the radian value identifying the position of the firm i and ω_h the radian value associated to consumer h's location: $d_{hi} = sin(min[|\omega_h - \omega_i|, 2\pi - (|\omega_h - \omega_i|)]/2)$.

[12] The two sides of Eq. (7) can be also interpreted as a welfare function. In Salop (1979) and Hotelling (1929) this function was linear because the authors aimed at solving the model analytically. We prefer instead to employ a non-linear version of the welfare function where the price and the distance enter

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In the presence of supply constraints consumers can browse through their ranking of suppliers trying to satisfy the residual demand.

Households hold deposit accounts at commercial banks $D_{h,t}$, returning a positive interest at the rate $r_{d,t}$, and participations in the equity of firms and banks $A_{h,t}$, yielding dividends when profits are positive. In each period households have to decide how to allocate their savings between these two types of financial assets. We implemented a simple portfolio function inspired by the *Tobinesque* approach to households' portfolio allocation (Brainard and Tobin, 1968). The fundamental insight we take from this approach is that households, in their role of financial investors, determine the desired allocation of their financial wealth by comparing the expected rates of return of the assets they can purchase: for simplicity reasons, we take the past rates of return yielded by deposits and past equity investments as a measure of these expectations. While deposits are a risk-free asset, the rate of return on equity investment is weighted by its perceived riskiness, proxied by the past extinction rate of firms and banks indicated by $Pr_t^{default}$.[13] Indicating by $lp_{h,t}$ the share or wealth that households desire to hold in the form of deposits, we have:

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

with $0 < \lambda < 1$ representing an exogenous upper threshold to the share of wealth that households want to hold in the form of deposits.

Households choose their deposit bank randomly, since every bank offers the same interest rate $r_{d,t}$ for simplicity reasons.

If we indicate 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 planned consumption and income levels, the desired level of equity and deposits can be then expressed as:

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

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

where $A_{h,t}^D - A_{h,t-1}$ is the desired investment in equity, which is bound to be non-negative.[14]

Households having a positive desired investment act together as an investment fund to create a new firm or a new bank. If funds collected are sufficient (i.e. above the threshold represented by the initial equity value which is randomly sampled, see Section 2.1.6), the new enterprise is created. Otherwise, households postpone their investment to the next periods and temporarily deposit the resources originally allocated to equity investment in their bank account. Conversely, if the quantity of funds collected is very high, more than one firm (bank) might enter the market in the same period.

2.1.2. Firms

Firms' desired output level $q_{i,t}^D$ depends on their sales expectations $q_{i,t}^e$ and the level of inventories inherited from the past $inv_{i,t}$. Furthermore, firms aim to keep a certain amount of inventories, expressed as a share θ of expected sales, as a buffer (Lavoie, 1992; Steindl, 1952).

$$q_{i,t}^D = q_{i,t}^e(1 + \theta) - inv_{i,t} \tag{11}$$

Prices $p_{i,t}$ and real sales expectations $q_{i,t}^e$ are revised adaptively from period to period according to a simple scheme depending on $q_{i,t-1}$ (the output produced by firm i in $t-1$), $\hat{q}_{i,t-1}$ (the quantities sold in $t-1$), and $q_{i,t-1}^{tot} = q_{i,t-1} + inv_{i,t-1}$ (the total amount of goods available for sales in $t-1$, equal to past production plus past inventories).

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

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

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

multiplicatively. The main implication is that the welfare extracted from the purchase of a given product will be significantly affected by a marginal change in the distance when the distance is low (i.e. the product is located in a neighborhood of the consumer's preferences), whereas the marginal variation of the welfare will be lower for higher values of the distance (i.e. when the product is far from the consumer's preferences). In the former case, a large variation of prices is thus necessary to keep the welfare constant, whereas in the latter case only a minor variation is required. By taking the logs, it is possible to show that the two sides of Eq. (7) come down to the original linear specification of Hotelling (1929).

[13] For simplicity reason we do not distinguish the riskiness of equity investments in banks and equity investments in firms, and we define the extinction rate as $Pr_t^{default} = \frac{I_{t-1}^{default} + Z_{t-1}^{default}}{I_{t-1} + Z_{t-1}}$, where $I_t^{default}$ and $Z_t^{default}$ are respectively the number of firms and banks defaulting in period t.

[14] Indeed, for simplicity reasons, we assume households cannot liquidate their participations in firms and banks. Furthermore, if consumption is frustrated by supply constraints, so that actual consumption ($C_{i,t}$) is lower than desired, deposits end up being higher than originally planned, whereas investment in equity sticks to its planned level.

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Eq. (12) states that if past sales exceeded expectations, firms adaptively increase both sales expectations and their selling price. When past sales were below their expected value and no supply constraint was binding (Eq. (13)), both expectations and prices are revised downwardly. Finally, when firms' past sales were below expectations due to the presence of a supply constraint (i.e. despite firms had exhausted all their available supply, see Eq. (14)) firms postpone any revision of prices and expectations to the next periods. Prices have a lower bound represented by unit costs of production: $p_{i,t} \geq \frac{w_{i,t}}{\phi_{i,t}}$, where $\phi_{i,t}$ is firm's i labor productivity in period t.

Firm's labor demand is then computed as: $l^D_{i,t} = q^D_{i,t}/\phi_{i,t}$. Output can be lower than desired if labor employed is less than needed due to the presence of financial constraints or if the firm has not been able to find workers willing to fill vacant positions at the firm's offered wage.

The salary $w_{i,t}$ offered by firm i is adaptively revised following a scheme similar to that characterizing workers' reservation wage. Eq. (15) shows that firms first check if they were able to fill all vacant positions in the previous period, comparing their past labor demanded $l^D_{i,t-1}$ and labor actually employed $l_{i,t-1}$. If labor employed was below the demanded level, they consider to increase the salary so to attract workers. If instead all vacant positions had been filled, they consider to reduce their offered wage so to increase their profit margin. However, the probability of occurence of these revisions depends on unemployment levels, as displayed in Eq. (15): reducing wages when unemployment is low exposes the firm to the risk of not filling its vacant positions, ending up being labor constrained; conversely, the risk is low if many workers are unemployed. Therefore, upward revisions are more likley to occur when unemployment is low, and less likely when unemployment is high. The opposite holds for downward revisions.[15]

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

Firms can also increase their profit margin by improving their productivity $\phi_{i,t}$. For this sake they invest in R&D activities: we employ a rule similar to Dosi et al. (2010) and later works, according to which funds dedicated to R&D are determined as a given share of expected nominal sales[16]:

$$R\&D^D_{i,t} = \gamma q^e_{i,t} p_{i,t} \tag{16}$$

Actual $R\&D_{i,t}$ is equal to $R\&D^D_{i,t}$ only if no financial or labor constraints are binding.

The amount of resources invested in R&D, in turn, determines the probabilities of enhancing firm's productivity by either carrying out an incremental innovation or by exploiting sectoral spillovers through imitation (Dosi et al., 2010). Therefore, firms are, in every period of the simulation, at the same time innovators and an imitators, the total investment in R&D (imitative and innovative) being defined by Eq. (16). As innovators, they try to come up with technical improvement on their own. As imitators they try to collect information on the productive techniques in use among their competitors and, in case they realize they are suffering a productivity gap with respect to the average of their competitors, they try to catch up through imitation.

Formally, the probability of success of these two types of R&D activities (i.e. innovation and imitation) is the same given the total investment in R&D, and it is given by:

$$Pr_{success_{i,t}} = 1 - e^{\frac{-\upsilon R\&D_{i,t}}{\Phi_{k,t} P_{k,t}}} \tag{17}$$

where $P_{k,t}$ and $\Phi_{k,t}$ are the average level of prices and the average productivity of the country.

Eq. (17) shows that the probability of success is a non-linear increasing function of the real investment on R&D activities ($R\&D_{i,t}/P_{k,t}$), divided by the average level of productivity ($\Phi_{k,t}$).[17]

When successful in innovating, firms update their labor productivity as shown in 18:

$$\phi_{i,t+1} = \phi_{i,t}(1 + U[0,\delta]) \tag{18}$$

If firms discover they have a productivity below the sector average they try to exploit sectoral spillovers through imitation to narrow the gap with the standards of production in the sector. When successful in imitating, they sample a new

[15] As for workers' reservation wage revision rule, also Eq. (15) has undergone a similar refinement compared to its previous version presented in Caiani et al. (2018a).

[16] Dawid et al. (2012) provides additional empirical evidence on the link between R&D and sales. This assumption is also in line with the theoretical insight provided by Silverberg and Verspagen (1996) and provides a way to avoid embedding too much volatility in R&D investment, in line with the empirical observation that R&D intensity tends to be relatively stable for firms over time. Finally, the finding by Cohen et al. (1987) that R&D intensity largely depends by the sector in which the firm operates justifies our simplifying assumption that firms have a constant and equal parameter γ expressing desired R&D as a share of expected sales. Since we did not find conclusive evidence on possible differences in the R&D intensity of tradable and non-tradable firms, we made the conservative choice of employing the same parameter for both types of firms. Please notice that Eq. (16) has been modified with respect to Caiani et al. (2018a) where R&D investment was defined as a share of the firms' expected wage bill, in order to avoid any possible bias in the design of our experiments on wages.

[17] This correction is required in order to prevent $Pr_{success_{i,t}}$ from continuously increasing as a consequence of the progressive rise of countries' potential output due to the higher levels of productivity $\Phi_{k,t}$ achieved during the simulation. Please notice that Caiani et al. (2018a) adopted two distinct functions for tradable and non-tradable firms dividing nominal R&D investment by the sector average prices and productivity levels, instead of the country ones. Eq. (17) provides a simpler and more reasonable formulation which looks at the dynamics of potential output in the country where the firms operate.

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productivity level in a range between their current one and the sector average. For tradable firms:

$$\phi_{i,t+1} = \phi_{i,t} + U[0, (\Phi_t^T - \phi_{i,t})] \text{ if } \phi_{i,t} < \Phi_t^T \tag{19}$$

For non-tradable producers:

$$\phi_{i,t+1} = \phi_{i,t} + U[0, (\Phi_t^{NT} - \phi_{i,t})] \text{ if } \phi_{i,t} < \Phi_t^{NT} \tag{20}$$

The new level of productivity achieved thanks to an innovation and/or an imitation is embed in the firm's production process starting from the next period.

Firms' costs of production and R&D investment can be financed using internal funds or external funding in the form of loans asked to domestic and foreign banks (L_{it}). Firms resort to bank credit only after internal funding has been exhausted, since the cost of external finance is usually higher due to market imperfections and information asymmetries (Meyers, 1984).[18]

Firms' demand for loans can be expressed as:

$$L_{i,t}^D = \begin{cases} w_{i,t} l_{i,t}^D + R\&D_{i,t}^D - D_{i,t}, & \text{if } w_{i,t} l_{i,t}^D + R\&D_{i,t}^D > D_{i,t} \\ 0, & \text{if } w_{i,t} l_{i,t}^D + R\&D_{i,t}^D \leq D_{i,t} \end{cases} \tag{21}$$

Firms can try to fulfill their funding needs asking credit to different banks. Nonetheless, they may end up being credit-constrained ($L_{i,t} \leq L_{i,t}^D$) (see Section 2.1.3). When this occurs, firms prioritize production over R&D. For simplicity reasons, loans are assumed to last only one period, being granted at the beginning and repaid at the end of each round, together with the interest accrued, similarly to the Monetary Circuit Theory (Graziani, 2003) and to Delli Gatti et al. (2010); Dosi et al. (2010); Riccetti et al. (2015).

Firms hold their funds at a randomly selected deposit bank, receiving 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 costs, and interests on credit:

$$\pi_{i,t} = p_{i,t} q_{i,t} + r_{d,t} D_{i,t} + \Delta INV_{i,t} - w_{i,t} l_{i,t} - R\&D_{i,t} - r_{i,t} L_{i,t} \tag{22}$$

Firms' net operating cash flows, 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 ($T_{i,t}^\pi$) and distribute dividends ($Div_{i,t}^\pi$) to equity holders, expressed as a share ρ of their residual net cash inflow.[19]

$$T_{i,t}^\pi = \begin{cases} \tau_{k,t} \pi_{i,t}^*, & \text{if } \pi_{i,t}^* > 0 \\ 0, & \text{if } \pi_{i,t}^* \leq 0 \end{cases} \tag{23}$$

$$Div_{i,t}^\pi = \begin{cases} \rho(\pi_{i,t}^* - T_{i,t}^\pi), & \text{if } \pi_{i,t}^* > 0 \\ 0, & \text{if } \pi_{i,t}^* \leq 0 \end{cases} \tag{24}$$

Dividends are distributed to equity holders proportionally to their participation in the firm's equity.

2.1.3. Banks

Banks offer demand deposit 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 create money endogenously providing 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 $A_{z,t}$: $L_{z,t}^{DS} = \mu_1 A_{z,t}$

Banks receive credit applications from both domestic and foreign firms. For each loan application, they compute a probability $Pr(Loan_{i,t})$ to grant it and an interest rates ($r_{i,t}$) to charge. These are defined as, respectively, a decreasing and increasing function of the borrowers' riskiness, proxied by their target leverage ($L_{i,t}^D / A_{i,t}$), where $A_{i,t}$ indicates the equity of firm i at period t:

$$Pr(Loan_{i,t}) = e^{-\iota_l \frac{L_{i,t}^D}{A_{i,t}}} \tag{25}$$

$$r_{i,t} = \chi \frac{L_{i,t}^D}{A_{i,t}} + r_t \tag{26}$$

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

If reserves $R_{z,t}^M$ are below the minimum level, banks apply to the National Central Bank lending facility, receiving cash advances ($L_{zCB,t}$) at the discount rate r_t to restore the mandated liquidity ratio. If instead banks have more reserves than

[18] Furthermore, given the cost of bank credit, the demand for loans is positive only if the expected revenue that can be generated by using these additional funds for production purposes is higher, given firms' sales expectations and prices.

[19] Taxes on profits generated in period t are paid in period $t+1$. Accordingly, also dividends generated in period t are paid to equity holders in period $t+1$.

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needed, the excess can be invested in the purchase of bonds ($B_{zk,t}$) issued by any member country k, which bring an interest rate $r_{bk,t}$ (Eq. (36)). Banks' probability of purchasing each tranche of a country's public debt depends on the public debt-to-GDP ratio (see Caiani et al. (2018a) for the details).

Banks' profits are then equal to:

$$\pi_{z,t} = \sum_{i,L_{iz,t}>0}^{I_{k,t}} r_{i,t} L_{iz,t} + \sum_{k,B_{zk,t}>0}^{I_{k,t}} r_{bk,t} B_{zk,t} + r_{re} R_{z,t} - BD_{iz,t} - r_{d,t} D_{z,t} - r_t L_{zCB,t} \tag{27}$$

where ($BD_{iz,t}$) indicates 'the "bad debt", that is non-performing loans due to borrowers' default.

Banks pay taxes on (positive) profits and distribute to equity holders a share ρ of net profits. These dividends are distributed between investors proportionally to the share of the bank's equity they own.

$$T^{\pi}_{z,t} = \begin{cases} \tau_{k,t}\pi_{z,t}, & \text{if } \pi_{z,t} > 0 \\ 0, & \text{if } \pi_{z,t} \leq 0 \end{cases} \tag{28}$$

$$Div^{\pi}_{z,t} = \begin{cases} \rho(\pi_{z,t} - T^{\pi}_{z,t}), & \text{if } \pi_{z,t} > 0 \\ 0, & \text{if } \pi_{z,t} \leq 0 \end{cases} \tag{29}$$

2.1.4. 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 (Gerali et al., 2010; Smets and Wouters, 2007; Taylor, 1993):

$$r_t = \bar{r}(1-\xi) + \xi r_{t-1} + (1-\xi)\xi^{\hat{P}}(\hat{P}_{t-1} - \hat{P}^*) \tag{30}$$

where $\bar{r}$ is the exogenous long run interest rate, ξ is the parameter defining the speed of the adjustment, $\xi^{\hat{P}}$ is the sensitivity to inflation, $\hat{P}_{t-1}$ is the past average level of inflation, and $\hat{P}^*$ is the inflation target.

National Central Banks hold reserves of commercial banks ($R_{CBk,t}$), accommodate their requests of cash advances ($L_{CBk,t}$), and possibly buy bonds issued by the country government ($B_{CBk,t}$) which remained unsold after private banks' purchases.

National Central Banks' profits ($\pi_{CBk,t} = r_{bk,t} B_{CBk,t} + r_t L_{CBk,t} - r_{re} R_{CBk,t}$) are automatically redistributed to the national government.

2.1.5. 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:

$$T_{k,t} = \sum_{h,y_{h,t}>0}^{H_k} \tau_{k,t} y_{h,t} + \sum_{i,\pi^*>0}^{I_k} \tau_{k,t}\pi_{i,t-1} + \sum_{z,\pi>0}^{Z_k} \tau_{k,t}\pi_{z,t-1} \tag{31}$$

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

The government balance is the difference between revenues from taxes and government spending, including interests paid on bonds. When negative, the government runs a deficit $DEF_{k,t}$. In the opposite case the government attains a budget surplus $SU_{k,t-1}$. Possible budget surpluses are set aside to fund public expenditure in the next period, thereby reducing the quantity of bonds to be issued.

The government determines in each period the level of public spending ($G_{k,t}$) and the tax rate ($\tau_{k,t}$) following an adaptive scheme, based on the discrepancy between desired and past levels of public expenditure on the one hand, and expected and admissible levels of public deficit on the other hand. The desired level of public expenditure $G^D_{k,t}$ is simply defined as the initial (exogenously set) real value of public spending G, adjusted for the country average level of prices $P_{k,t}$ and average productivity $\Phi_{k,t}$, so to keep the dimension of $G^D_{k,t}$ roughly stable compared to aggregate GDP: $G^D_{k,t} = P_{k,t}\Phi_{k,t}G$. In addition, governments are committed to make efforts not to exceed a deficit-to-GDP threshold indicated by d^{max}. Public expenditure and tax rates are then revised according to the following scheme:[20]

$$\text{if } d_{k,t-1} \geq d^{max} \text{ and } G^D_{k,t} \leq G_{k,t-1} : \begin{cases} G_{k,t} = G_{k,t-1}(1 - U[0,\delta]) \\ \tau_{k,t+1} = \tau_{k,t}(1 + U[0,\delta]) \end{cases} \tag{32}$$

$$\text{if } d_{k,t-1} \geq d^{max} \text{ and } G^D_{k,t} > G_{k,t-1} : \begin{cases} G_{k,t} = G_{k,t-1} \\ \tau_{k,t+1} = \tau_{k,t}(1 + U[0,\delta]) \end{cases} \tag{33}$$

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

[20] To avoid unreasonable high or low values, the tax rate is bound to vary within the range $\{\tau_{min}, \tau_{max}\}$, whereas $G_{k,t}$ is bound between a minimum and maximum share of GDP: $\{g_{min}Y_{k,t}, g_{max}Y_{k,t}\}$.

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

In each period, 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:

$$r_{bk,t} = r_t + \chi B_{k,t}/Y_{k,t} \tag{36}$$

Newly issued bonds (for a total value of $B_{k,t}$) are split into 100 tranches ($b_{k,t} = B_{k,t}/100$) and put on the bond market where they are purchased by commercial banks, and by the national Central Bank for the possible residual part.

Finally, national governments step-in to guarantee depositors in case of default by a domestic bank. For this sake, governments issue an additional batch of bonds, which is directly purchased by the Central Bank, and uses the liquidity collected to reimburse households and firms who lost their deposits in the default.

2.1.6. Firms' and banks' endogenous entry and exit

Part of households' savings is invested in the creation of new firms and new banks (see Section 2.1.1).

The new entrant will be a bank when either the ratio between banks' and firms' number, or the ratio between banks' and firms' total net worth are below a given percentage η. Otherwise, the new entrant will be a firm. The new firm will be a tradable with probability c_T, or a non tradable with probability $1 - c_T$. In this way we aim to avoid excessive imbalances in the relative dimension of the banking, tradable, and non-tradable sectors.

The initial equity level of the new organization is sampled in a range between the net worths of the smallest and larger incumbents: the first h investors required to collect this amount of funds become its shareholders. If funds invested by households are lower than the randomly sampled initial net worth, no firm (bank) is created and funds originally allocated by households to equity investment are deposited at banks.

The initial productivity (ϕ), price ($p_{i,t}$), and offered wage ($w_{i,\,t}$) of newly created firms are sampled within a range going from the correspondent lowest to the highest values of incumbent firms operating in the sector. Sales expectations ($q^e_{i,t}$) are the maximum between the random value sampled in the range between the lowest and highest values of incumbents and $\frac{A_{i,t}}{w_{i,t}}\phi_{i,t}$, this latter representing the amount of goods feasibly producible given the firm's initial values of equity, wage, and productivity sampled.

Firms whose net worth is below a threshold level, defined as the wage they offer to workers $F_t = w_{i,t}$, default. Similarly, banks having a net-worth below the national average wage default.[21]

A default by a firm implies a non performing loan for creditors. The larger the bad debt suffered by banks, the worse the effect on their balance sheet. In the rare case of a default by a bank the government steps-in and issues additional bonds to reimburse depositors, as discussed in Section 2.1.5.

2.2. Simulation scheduling and simulations setup

The sequence of events taking place within each period of the simulations follows Caiani et al. (2018a):

1. Firms determine their desired production, their labor demand, the price of their output, the wage offered, and their desired R&D investment.
2. Firms interact with banks on the credit market and possibly receive loans. Banks possibly ask cash advances to the Central Bank to satisfy the mandatory liquidity ratio.
3. Firms interact with workers on the labor market.
4. Workers are paid and employed to produce firms' output and to perform R&D. Dividends generated in the previous period are distributed to equity holders, summing up to their current income.
5. Governments calculate revenues from taxes (on past period profits and current period households' income), determine the level of public spending and the tax rate for the next period, repay bonds plus interests to bond holders, and determine the quantity of bonds to be issued.
6. Bonds are put on the bond market where are purchased by commercial banks. The possible residual part is purchased by national Central Banks.
7. After having paid taxes and received the tax-exempt monetary transfer from the government, households compute their demand for consumption goods and interact with tradable and non-tradable firms on the corresponding good markets.
8. Firms and banks compute their profits and update their net worth and shareholders' equity accordingly. Taxes and dividends to be paid in the next period, respectively, to the government and to equity holders are then computed.
9. Defaulted firms and banks exit the market. Households equity investment takes place and, if enough financial resources are collected, new firms and banks are created.

[21] In this way we remove from the simulation not only firms having a negative net-worth but also microscopic firms whose contribution to the dynamics of the model is negligible, thus representing just a computational burden.

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The calibration of the model largely resembles that employed in Caiani et al. (2018a). Only a few parameter values have been changed, partly as a refinement of the simulation setup, but mostly as a consequence of the amendments made to the wage revision rules of workers (Eq. (1)) and firms (Eq. 15), and to the R&D investment specification (Eqs. (16) and (17)).[22]

Table 2in the appendix displays the value of the parameters employed in the baseline specification, which were the result of a combination of an empirically plausible calibration and a tentative investigation of the parameter space: with this configuration the model yields a quite stable dynamics over the time-span considered and the properties of key economic variables - such as real GDP and productivity growth rates, inflation rates, unemployment rates, debt-to-GDP ratios, exports and imports, etc. - are economically reasonable and broadly resemble the properties of their empirical counterparts.

Table 3in the appendix, which presents a battery of statistics on key economic variables generated by the model and compares them with data for the European Monetary Union, highlights that our artificial Monetary Union produces a sound scenario, broadly comparable to the EMU (last two columns) under many respects. In addition, before executing the experiments described in the next sections, we followed the procedure presented in Caiani et al. (2018a) - in line with the well-established macro AB validation routine started with Dosi et al. (2010) - and verify the consistency between the properties of the times series generated by the model and a selection of key stylized facts concerning:

- The relative volatility of real GDP, consumption, investment, unemployment, exports and imports;
- The cyclicality of consumption, exports, imports, public spending and public spending over GDP, and unemployment (Uribe and Schmitt-Grohé, 2017);
- The differential between inflation and labor productivity growth in the tradable and non-tradable sectors (Bernard et al., 2003; 2007; Bernard and Jensen, 1999; De Gregorio et al., 1993);
- The distribution of firm and bank size(Stanley et al., 1995);
- The persistency of countries real GDP and labor productivity differentials.

Yet, it must be stressed that this procedure must be fundamentally regarded as a tentative 'output validation', that is an *ex post* validation: although we employed plausible values for the "observable" parameters (e.g. the R&D intensity or the propensities in the consumption function) or take them from the literature (e.g. the parameters of the Taylor rule), we did not try to calibrate or estimate the model on actual data. Given its simplified structure, the model is not intended to make precise forecasts, nor to give precise quantitative policy prescriptions to policymakers. This tentative empirical validation must then be taken with a grain of salt: we do not aim to match actual data for European countries, but rather to check if our baseline provides a "sound" and "plausible" scenario, thereby allowing to get some relevant and useful theoretical insights from the experiments conducted in order to investigate the relationship between wages dynamics and countries' economic performance. In this respect, our investigation might be labeled as an 'empirically sensible theoretical exercise'.

Finally, the model employs a simple and intuitive procedure to carry out the task of setting up in a Stock Flow Consistent manner the initial values of stocks and flows for individual agents and for the economy as a whole, so to respect Copeland's quadruple entry principle (Copeland, 1949; Godley and Lavoie, 2007). The rationale of this procedure, explained in detailed in Caiani et al. (2018a), is the following: instead of setting these initial values exogenously, we let them to be progressively created and accumulated in the initial phase of the simulation. To be more precise, we start from a situation where there are no stocks in the economy, and no firms and banks either. Following a procedure inspired by the "SIM" model presented in Godley and Lavoie (2007), the initialization phase is then triggered by public spending, as the government makes an initial transfer to resident households. National Central Banks buy government bonds, thereby injecting legal currency in the economic system. This money is saved by households (since there are initially no goods to purchase for consumption purposes) and invested in the creation of new firms which start to employ workers, produce goods (which are then sold to households), and invest in R&D. The government then starts to collect taxes on income and profits. As the number of firms increases, also banks are created. Households and firms then deposit their legal currency at these newly created banks. Banks start to grant credit to firms so that the system. Private banks start to purchase government bonds. As tax revenues and GDP increase - since more and more firms are in business - the public debt-to-GDP ratio rapidly declines and stabilizes to reasonable levels. International flows of goods, deposits and reserves between countries arise. Supranational credit-debt relationships, generating international flows of interests also arise since commercial banks grant loans also to foreign firms and purchase public debt bonds of foreign countries. Defaults and new entries tend to offset each other and the number of firms and banks stabilizes. Firms and countries become more and more heterogeneous as a consequence of the path-dependent processes triggered by the outcome of their past R&D and by their past economic performance. Eventually, the model progressively exits its transition phase and starts to display stable properties.

After the model stabilizes, its consistency with empirical stylized facts can be checked, as we explained here above, and policy experiments can be carried out: the next section is dedicated to their analysis.

[22] See Sections 2.1.1 and 2.1.2 for a discussion of these refinements.

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Table 1
Experiment design: alternative wage wrowth regimes.

	Wage inflation		Baseline	Wage compression	
υ	0.512	1.054	1.625	2.231	2.877
$e^{-\upsilon u_{t-1}}$ at $u_{t-1} = 10\%$	95%	90%	85%	85%	75%

3. Results

3.1. Experiment design

In the next sub-sections we present and discuss the results of our simulation experiments designed to study the impact of alternative wage growth patterns on the economic performance of individual countries, and of the Monetary Union as a whole.

For convenience, we recall hereunder the two adaptive heuristics employed by workers and firms to revise their reservation and offered wage, respectively.

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

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

The two pairs of rules highlight that the direction of the possible revision undertaken by workers and firms depends on an agent-specific condition: workers compare the quantity of labor sold with the quantity supplied, whereas firms compare the quantity purchased with the quantity demanded.

However, the revision only occurs with a probability depending on the aggregate rate of unemployment, thus reflecting the endogeneity of workers' and firms' bargaining power: upward revisions are less likely when unemployment is high, convincing workers to adopt a more cautious behavior, while they become more likely if unemployment is low, inducing workers to increase their wage claims. Similarly, on the other side of the labor market employers know that workers are more willing to accept lower wages when they are overabundant, and that wages should instead rise to increase the probability of filling vacant positions when workers are a scarce resource. This probability depends on the exponential function $e^{-\upsilon u_{t-1}}$ and the value set for the parameter υ: a higher υ reduces the probability of rising wages and increases the probability of wage reductions. In a policy perspective, a reduction of υ represents a parsimonious and intuitive way to mimic the effect of institutional reforms aiming to strengthen workers' bargaining power, while an increase of the parameter shifts the bargaining power in favor of employers. Wage expansionary scenarios thus take the form of a decrease of υ occurring at period 500. An increase at period 500 of υ instead corresponds to a slowdown of wages. Table 1 displays all the values of υ employed in the simulation experiments, and the corresponding values assumed by the exponential term $e^{-\upsilon u_{t-1}}$ at a past level of unemployment equal to 10%. Table 1 shows that values of υ were set so that the value attained by $e^{-\upsilon u_t}$ at $u_{t-1} = 10\%$ changes by five percentage points between each scenario.[23]

For the sake of providing an exhaustive analysis of the twofold role of wages in driving the dynamics of the economic system, as they represent at the same time a major source of nominal aggregate demand and a determinant of firms' international cost competitiveness, we perform several different simulation experiments: Section 3.2 considers an acceleration of wages, implemented through a reduction of the parameter υ at period 500, occurring in a single randomly-chosen country. Section 3.3 considers the opposite case of a wage moderation strategy, that is an increase of υ, in a single randomly-chosen country.[24] Section 3.4, instead, investigates the effect of a coordinated change in the wage growth pattern of all countries. Section 3.5 enriches the analysis checking if and how the results discussed in Section 3.4 are modified when we change the number of countries involved in the simulations and the elasticity of consumers' demand to prices. For each simulation experiment presented, 50 Monte Carlo simulations have been run. Each period ideally represent a quarter. Simulations last 1000 periods.

3.2. Experiment: wage acceleration in a single country

In this sub-section we consider the effects of a reduction of the parameter υ from 1.625 to 0.512 occurring in a randomly sampled country at period 500. As Table 1 shows, this shock increases the value assumed by $e^{-\upsilon u_{t-1}}$ from 85% to 95% at an unemployment rate of 10% so that the probability of an upward revision at that level of unemployment (and provided

[23] This factor is then scaled by the parameters υ_H and υ_F for households and firms respectively. The rationale of these scaling parameters has been already discussed in Section 2.1.1.

[24] For space reasons in these two sections we display just the experiments performed using the extreme values of υ in Table 1. Results are similar, though milder, for intermediate values.

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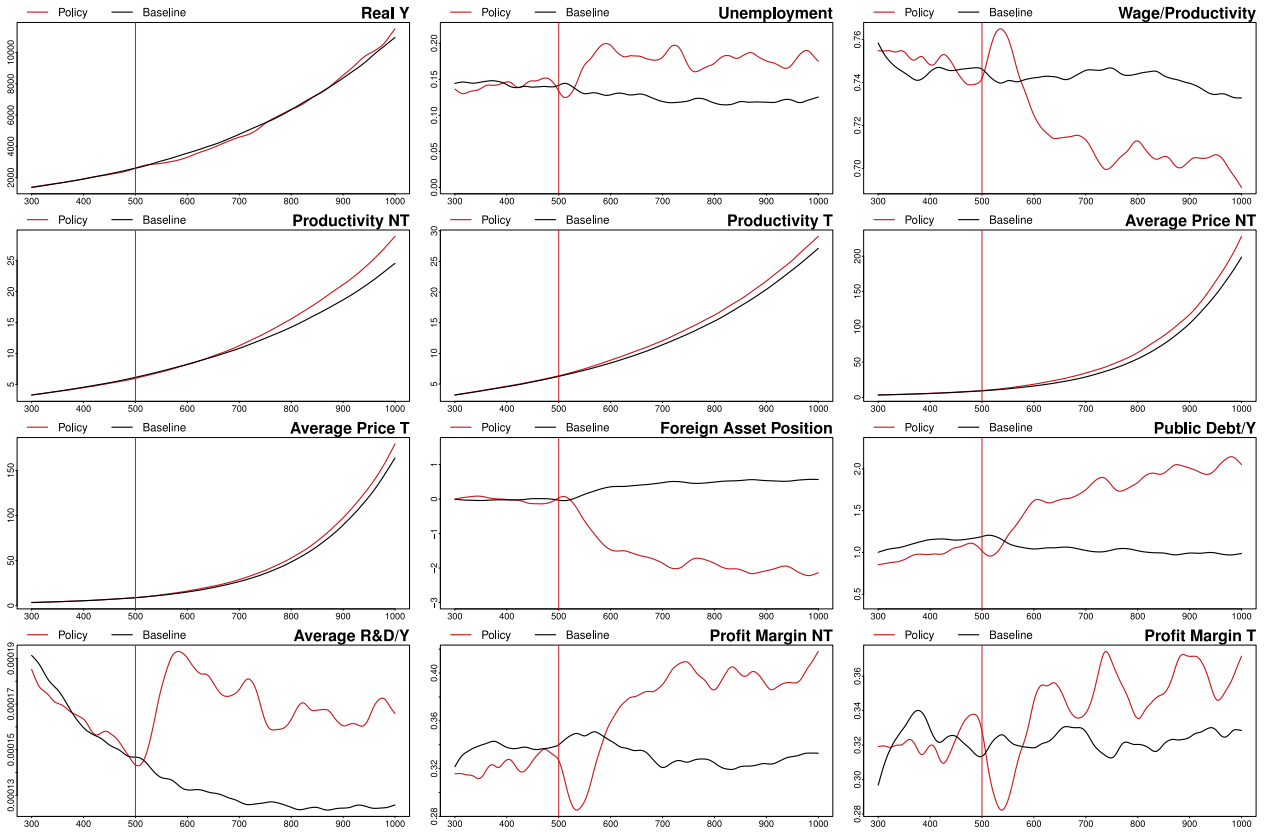

Fig. 2. Wage acceleration in one randomly-chosen country. Lines represent average trend across Monte Carlo simulations for each variable. Dashed lines are confidence intervals. The black line refers to the average of the $K-1$ countries which stick to the baseline configuration. The red line refers to the randomly-sampled country where the wage growth pattern is enhanced. Top: Real GDP (left), Unemployment (center), Average Wage/ Average Productivity (right). Second row: Average Productivity in the non-tradable sector (left), Average Productivity in the tradable sector (center), Average Prices in the non-tradable sector (right). Third row: Average Prices in the tradable sector (left), Foreign Asset Position /GDP (center), Public Debt/GDP (right). Fourth row: Average R&D Investment by individual firms as percentage of GDP (left), Profit Margin in the tradable sector (right), Profit Margin in the non-tradable sector (left). Average variables referring to firms are weighted for firms' market shares. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

that the agent-specific condition is satisfied) increases by $\upsilon_H \cdot 10\%$ percentage points for households and $\upsilon_F \cdot 10\%$ percentage points for firms, whereas the probability of a downward revision decreases by the same amount. Due to space constraints, we refer to the case of a Monetary Union composed of $K = 5$ countries. Results are qualitatively robust under scenarios with 2, 10, and 15 countries.

This experiment is particularly useful since it allows to highlight the main processes triggered by the wage growth regime switch on both the demand and supply sides of the economy: on the demand side, wages exert a direct effect on the domestic demand for non-tradable and tradable goods, part of the latter taking the form of imports from abroad. On the supply side, wages concur to determine firms' unit costs of production, thereby affecting their profit margins and the international competitiveness of tradable firms. The evolution of wages, unit costs, and profit margins influences the process of Schumpeterian competition between firms by shaping a more or less selective competitive environment which steers the evolution of the industry towards more or less concentrated market structures. In turn, the number and average dimension of firms affect their average R&D investments, technological progress, and the dynamics of labor productivity.

Figures in panel 2 display the dynamics of key economic variables. As a consequence of the acceleration of wages occurring in period 500, firms' unit costs of production, measured by wages/productivity, initially rise (right side on the top of panel 2). The rise of unit costs is not perfectly offset by a proportional increase in prices, which change only gradually as a consequence of their adaptve revision rule. Furthermore, price increases risk to reduce the attractiveness of firms' products to customers, in particular in the tradable market where firms face the pressure of international competitors. This implies that workers' real purchasing power initially increases, stimulating real demand for both tradable and non-tradable goods. However, it also implies that the profit margin of firms shrinks as the realized markup is lower (center and right figures on the bottom row of panel 2) despite the progressive rise of inflation.

In the aftermath of the wage expansionary turn, net exports of the country thus tend to drop due to a substitution effect, because foreign tradables are slightly cheaper than those domestically produced. Furthermore, imports from abroad

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Fig. 3. Wage acceleration in one randomly-chosen country. Lines represent average trend across Monte Carlo simulations for each variable. Dashed lines are confidence intervals. The black line refers to the average of the $K-1$ countries which stick to the baseline configuration. The red line refers to the randomly-sampled country where the wage growth pattern is enhanced. Top: Number of Innovations achieved (left), Number of Firms in the non-tradable sector (center), Number of Firms in the tradable sector (right). Second row: Average Firm Size (index, period 500 = 100) in the non-tradable sector measured by sales (left), Average Firm Size (index, period 500 = 100) in the tradable sector measured by sales (center), Average Firm Size (index, period 500 = 100) in the non-tradable sector measured by number of employees (right). Third row: Average Firm Size (index, period 500=100) in the tradable sector measured by number of employees (left), Average Productivity Gap suffered by defaulting non-tradable firms measured by the percentage difference between the average productivity of defaulting and surviving firms in the domestic non-tradable sector (center), Average Productivity Gap suffered by defaulting tradable firms measured by the percentage difference between the average productivity of defaulting domestic tradable firms and surviving firms (domestic and foreign) operating in the common tradable good market (right). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

also rise due to an income effect, because higher wages increase total demand, including the demand for imports. This can be appreciated by looking at the Net Foreign Asset Position (center figure in the third row of panel 2) of the country which significantly worsens, falling into a negative territory meaning that countries pursuing a wage expansionary strategy in isolation tend to become, on average, net debtors.

All in all, this negative external effect seems to outweigh the positive income effect of wages on aggregate demand, in particular for non-tradables. Therefore, the economy initially experiences a slowdown of real GDP dynamics and a significant fall in employment levels (first and second figure in panel 2, respectively). The ensuing reduction of tax revenues causes public Debt-to-GDP ratio surges (right side of the third row of panel 2).

However, the dynamic process triggered by the wage expansionary turn allows to stabilize the system and revert the slow-down in the medium and long-run. In order to appreciate these endogenous mechanisms, we must look at what happens on the supply side of the economy. The expansionary turn of wages, by reducing firms' profit margins, creates a tougher environment for domestic firms, exacerbating firms' selection process. Though many factors may concur to cause the default of a firm, less productive firms are, on average, more prone to default, in line with a Schumpeterian interpretation of firms' competition process, as depicted in the famous models of 'Schumpeterian competition' developed by Nelson and Winter (1993; 1977; 1982; 1984). In fact, given their higher unit costs of production, they find themselves stuck between a rock and a hard place: either they see their profit margin vanishing or they increase the price to preserve it, at the cost of making their output less attractive to consumers. The center figure in the bottom row of panel 3 shows that defaulting non-tradable firms display, on average, a lower productivity level compared to the sector average. The acceleration of wages 'raises the bar' to stay on the market, causing the exit of firms that would have otherwise survived: in fact, the gap between the average productivity of defaulting and non-defaulting domestic non-tradable firms becomes narrower, both in absolute terms and relatively to other countries where wages stick to the old growth pattern, testifying the exacerbation of firms' Schumpeterian selection process. The strength of this selection mechanism is amplified for tradable producers, as they face the competition of firms operating in foreign countries, where wages did not accelerate:[25] their prices will thus be slightly above the average, but international competition prevents them from increasing prices too much compared to

[25] Conversely, non-tradable firms, as time goes by, can partly recover their profit margin by rising prices, since the rise of wages also contributes to increase the demand for their products, and given the fact that the rise of wages affects all non-tradable firms equally.

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foreign competitors (left side on the third row of panel 2), further squeezing their profit margin. This raises the bar further: not only the average productivity gap suffered by defaulting tradable firms in the country where wages accelerate (red line in the right figure at the bottom of panel 3) shifts upwards but, for a prolonged period, the line is close, or even above, zero. This reveals that the selection process for domestic tradable firms is so exacerbated that many of the firms defaulting actually have a productivity in line with, when not above, the average of all tradable firms in the Union.

The stronger selection process triggered by the rise of wages, which fosters the exit of more firms in the bottom of the productivity distribution, is a first fundamental driver of the model dynamics concurring to explain the rise of productivity in the country where wages accelerate (first and second figure in the second row of panel 2).

However, there is a second and possibly more fundamental driver. The tougher environment increases defaults and reduces the number of firms in business (last two figures in panel 2). Since surviving firm can benefit from the rise of domestic aggregate demand and exploit at the same time the space left by defaulting firms, they tend to grow in dimension. The industry structure emerging in the country following a wage expansionary strategy in isolation tends to be more concentrated, compared to the baseline scenario and relatively to other countries, being characterized by fewer and bigger firms: the first and second figures in the center row of panel 3 show that the average firm dimension, measured by real sales, grows faster in the wage expansionary country; similarly, the last and first figures of the second and third rows testify that firms in this country also tend to be bigger in terms of workforce employed. This, in turn, exerts a fundamental effect on domestic firms' innovative behavior: given that R&D investment is related to firm dimension through Eq. (16), the average R&D investment by firms in the country following a wage expansionary strategy tends to be higher, as the first figure in the fourth row of panel 2 displays. Being concentrated on fewer and bigger firms, rather than dispersed among many small ones, R&D investments tend to be more effective and the number of innovations achieved increases (first figure of panel 3). As a consequence, labor productivity tends to grow faster in the country where wages grow faster (first and second figure in the second row of panel 2).

Eventually, the enhanced labor productivity dynamics outweigh the rise of wages, thereby contributing to reduce unit labor costs of production (right side on the top of panel 2). In addition, the greater productivity reduces labor requirements for unit of output, keeping unemployment higher and thus partly counteracting the expansionary shift of wages. The reduction of unit labor costs tends to translate into an increase of profit margins (center and right side of the bottom row of panel 2) rather than in price reductions since keeping the price close to, or just below, the average one is generally sufficient to preserve firms' price competitiveness, so that firms have no incentive to reduce prices further despite their improved cost competitivenss. This explains why the Net Foreign Asset Position is stabilized but not reverted, as the country displays, on average, a balanced trade account while continuing to roll-over the stock of debt accumulated in the aftermath of the wage expansionary turn.

Sooner or later, the rise of labor productivity allows real GDP to recover and to catch up with other countries, or even overtake them, as displayed by the first figure in panel 2. This observation highlights that the system ends up displaying hysteresis in the dynamics of unemployment which remains higher, but not in that of real GDP, which catches up after the initial drop. The acceleration of real output indeed is not enough to compensate the acceleration of labor productivity, so that technological progress ends up being labor-saving when the expansionary wage 'strategy' is pursed by a single country in isolation. Finally, it must be noticed that, as GDP recovers, also the dynamics of public debt starts to fluctuate around stable levels in the medium and long run.

3.3. Experiment: wage moderation in a single country and global effects of isolated strategies

An increase of the parameter υ for a single country, corresponding to the case of an 'isolated' wage moderation strategy, gives rise to a specular dynamics with respect to that analyzed in Section 3.2.[26] The panel 4 presents a selection of key economic variables referring to this scenario. As in the former case, we distinguish between short and medium-long term effects.

A relative slow-down in the growth of wages reduces unit labor costs (right side on the top of panel 4) and increases firms' profit margins (center and right side on the bottom of panel 4). However, as prices adapt, the enhanced competitiveness of domestic tradable firms and the fall of imports due to the contraction of aggregate demand improve the trade balance: the Net Foreign Asset Position of the country where wages slow-down (second figure of the third line of panel 4) thus turns positive as the country accumulates funds and becomes a net creditor. This positive external effect initially offsets the depressing effects of wage moderation on domestic demand, causing a slight improvement of real GDP and a reduction of unemployment. As a consequence, also public debt-to-GDP ratios tend to fall and stabilize below the average of other countries (third graph on the third line of panel 4)

However, the milder pressure exerted by wages on firms' profit margins dampens the process of 'Schumpeterian competition'. When a country follows a wage moderation strategy its industries tend to converge towards a more fragmented structure characterized by more and smaller firms. R&D investment, as a consequence, is dispersed among a myriad of

[26] The experiment considers the effects of a change in the parameter υ from 1.625 to 2.876, which corresponds to a reduction of $e^{-\upsilon u_{t-1}}$ from 85% to 75% at an unemployment rate of 10%. The slowdown in wage growth pattern starts from period 500. Results presented in the plots of this sub-section refer to simulations with 5 countries. Results are robust under scenarios with 2, 10, and 15 countries.

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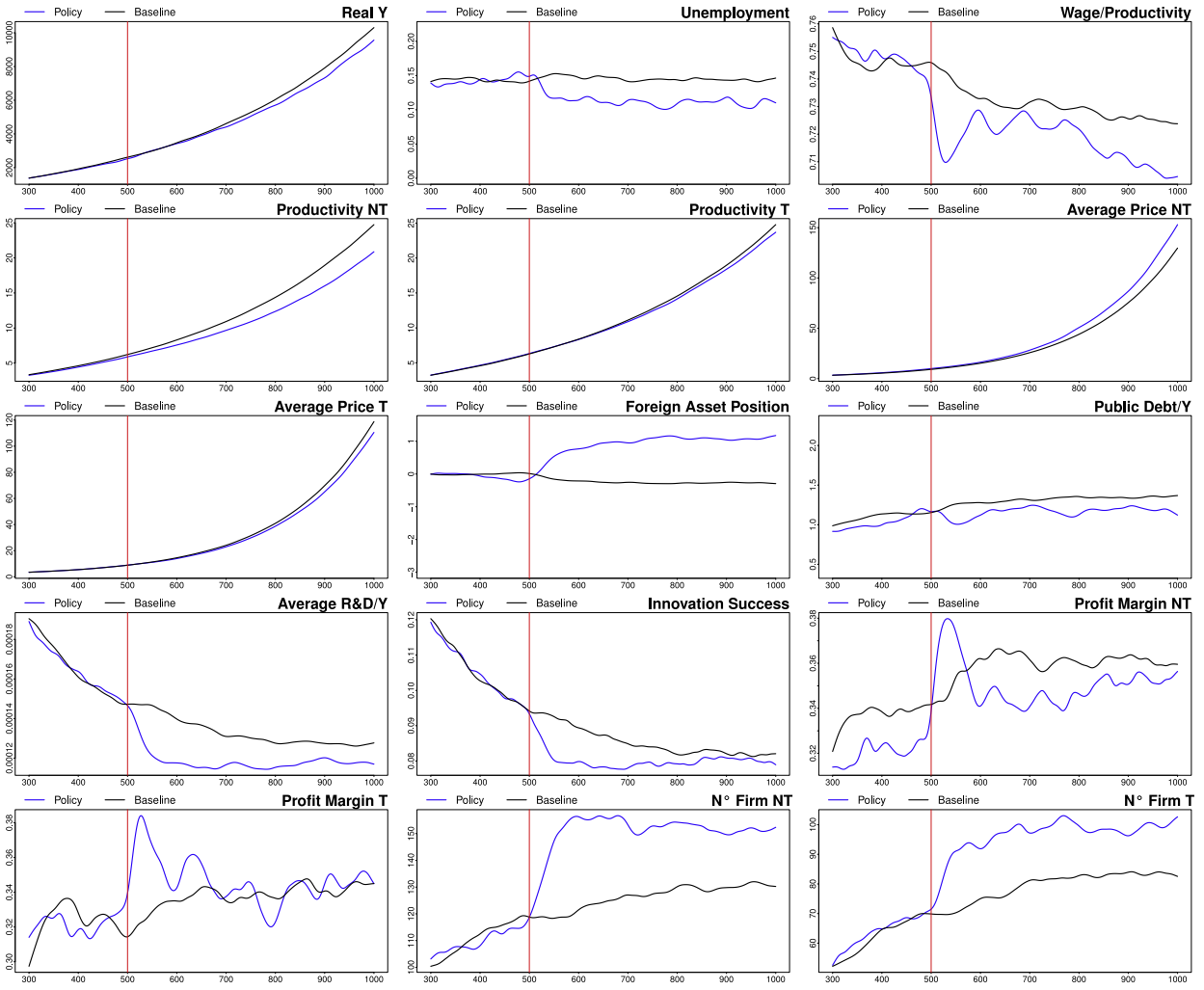

Fig. 4. Wage moderation in one randomly-chosen country. Lines represent average trend across Monte Carlo simulations for each variable. Dashed lines are confidence intervals. The black line refers to the average of the $K-1$ countries which stick to the baseline configuration. The red line refers to the randomly-sampled country where the wage growth pattern is dampened. Top: Real GDP (left), Unemployment (center), Average Wage/ Average Productivity (right). Second row: Average Productivity in the non-tradable sector (left), Average Productivity in the tradable sector (center), Average Prices in the non-tradable sector (right). Third row: Average Prices in the tradable sector (left), Foreign Asset Position /GDP (center), Public Debt/GDP (right). Fourth row: Average R&D Investment by individual firms as percentage of GDP (left), Number of Innovations achieved (center), Profit Margin in the tradable sector (right). Fifth line: Profit Margin in the non-tradable sector (left), Number of Firms in the non-tradable sector (center), Number of Firms in the tradable sector. Average variables referring to firms are weighted for firms' market shares. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

small firms loosing efficacy (left and center figures in the fourth row of panel 4). Innovation dynamics and labor productivity growth thus slowdown (left and center figures in the second row of panel 4). While the ensuing productivity gap suffered by tradable firms is partly mitigated by their ability to exploit international spillovers through imitation, which allows them to partially catch up, the gap is considerably larger for non-tradable firms, which can only imitate their domestic competitors.

In the medium and long run, this productivity slowdown dampens the labor-saving effect of technological progress allowing unemployment to stay low, but also prevents real GDP growth from keeping the pace with other countries (second and first figure on the top of 4, respectively).

Eventually, the slowdown of labor productivity growth, coupled with low unemployment levels which partly counteract the effects of wage moderation improving workers' bargaining power, tend to bring unit labor costs and firms' profit margins back to the average levels.[27]

[27] Interestingly, given the severe productivity gap suffered by non-tradable firms, unit costs of production end up being higher than in other countries within this sector, explaining the lower profit margins and the higher prices (third figures in the second and fourth rows of panel 4).

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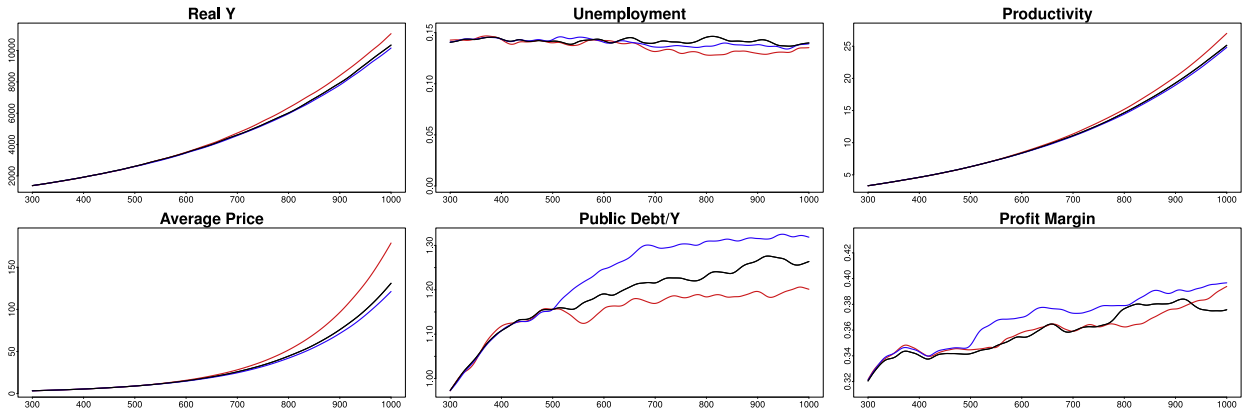

Fig. 5. Wage acceleration vs wage moderation in one randomly-chosen country: global effects on the Union. Lines represent average trend across Monte Carlo simulations for each variable. Dashed lines are confidence intervals. The black line refers to the average across all countries in the baseline configuration. The red line refers to the average across all countries corresponding to the experiment of wage acceleration in one random country, the blue line refers to the average across all countries in the experiment of wage moderation in one random country. First row: Real GDP (left), Unemployment (center), Average Productivity (right) in the non-tradable sector (left), Average Productivity in the tradable sector (center), Average Prices in the non-tradable sector (right). Second row: Average Prices (left), Public Debt/GDP (center), Average Profit Margin (right). Average variables referring to firms are weighted for firms' market shares. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

The findings and the mechanisms discussed in these two subsections are consistent with the empirical insights provided by Kleinknecht (1998); Kleinknecht et al. (2014); Vergeer and Kleinknecht (2014) who show that weaker wages tend to cause a slowdown of labor productivity growth, as they lessen the process of Schumpeterian competition allowing less innovative firms to survive by exploiting the lower labor costs, while abstaining from investing in R&D (whereas the opposite occurs if wage growth is sustained).

Before moving to the next experiment it must be noticed that the previous plots compare the averages for countries where υ changes with the average for the other $K-1$ countries which continue to stick to the baseline value of υ. However, what are the global effects of these changes on the overall performance of the Union? Figures in panel 5 assess the effects at the Union level in the previous two scenarios, comparing them with the baseline case.

Interestingly, these figures highlight that a reduction of υ generates a slight improvement of the Union average performance: real GDP and labor productivity are slightly higher, while public debt-to-GDP and unemployment levels are lower. This suggests that a faster increase of wages in a country tends to provide benefits to the rest of the Union, whereas a slowdown in wage growth seems to result in a slacker average economic performance at the global level.

What would then happen if countries were able to coordinate their wage strategies, that is if υ were changed in the same way and in all countries simultaneously? The experiment discussed in the next sub-section investigates this scenario.

3.4. Experiment: coordinated wage growth patterns

The deregulation of labor markets aiming to avoid excessive growth of wages has been often proposed in the economic debate as the golden rule to which every country should conform. This view has been discussed in the introduction with particular reference to the Euro Crisis: the Neoclassical interpretation, well represented by the thesis presented in Sinn (2014a,b), contends that peripheral countries should deregulate their labor markets in order to embrace the wage moderation strategy that has been the key of core countries' success. This analysis was fiercely opposed by scholars - mainly, but not exclusively, in the Keynesian tradition - who believe Germany has pursued a 'beggar thy neighbor' strategy which could not work if generalized to all European economies, advocating instead a coordinated strategy of wage increases (see for example Flassbeck and Lapavitsas (2013); Onaran and Obst (2016); Stockhammer (2011); Stockhammer and Sotiropoulos (2014)).

This debate provides the rationale for the simulation experiment presented in this section. While the previous section investigated the effects of changes in the growth pattern of wages occurring in single countries, we now consider the effects of a coordinated change implemented in all countries at once. As for the previous experiments, wage moderation and wage expansionary scenarios take the form of a change in the value of the parameter υ occurring at period 500. However, in this new experiment the value of the parameter is modified for all countries at once. We conducted four different simulation experiments employing the values displayed in Table 1, and we compare them with each other and with the baseline scenario. For each experiment, 50 Monte Carlo repetitions have been carried out. For space and explanatory reasons, in this section we refer to the case of a Monetary Union composed of five countries. However, Section 3.5 shows that results are robust across simulation experiments conducted with 2, 5, 10, and 15 countries.

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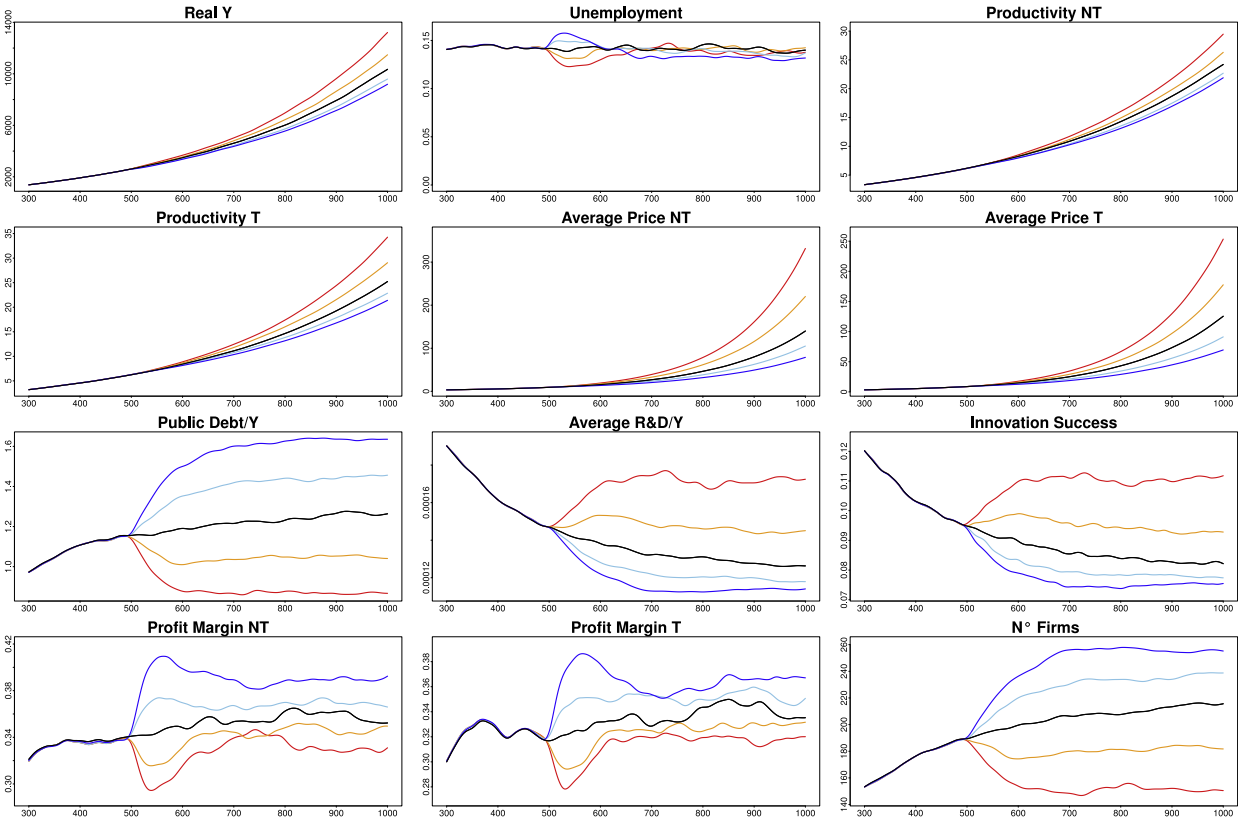

Fig. 6. Alternative Wage Growth Patterns in all countries. Lines are Monte Carlo average of variables average trends across countries. Dashed lines are confidence intervals. Black line: baseline scenario ($\upsilon = 1.625$). Red line: wage acceleration with $\upsilon = 0.512$. Orange line: wage acceleration with $\upsilon = 1.054$. Light blue line: wage moderation with $\upsilon = 2.231$. Blue line: wage moderation with $\upsilon = 2.877$. First row: Average Real GDP, Average Unemployment, Average Productivity in the non-tradable sector. Second row: Average Productivity in the tradable sector, Average Prices in the non-tradable sector, Average Prices in the tradable sector. Third row: Average Public Debt/GDP, Average R&D Investment by individual firms as percentage of GDP, Average Number of Innovations achieved. Fourth row: Average Profit Margin in the tradable sector, Average Profit Margin in the non-tradable sector, Average Number of Firms. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Panel 6 presents the main results of the simulation experiments performed. Given the objective of this test and the fact that countries are now characterized by the same wage growth regime, graphs display the average trends of variables across countries and their confidence interval.[28]

The discussion presented in Sections 3.2 and 3.3 provides a useful conceptual map to interpret the results of this section. The main difference is given by the fact that, when all countries follow a similar strategy towards wages, the relative advantages and disadvantages associated to each type of policy in terms of international competitiveness tend to be balanced out, leaving the relative international position of the Union member countries unaltered. In other words, a change in the wage growth pattern does not affect international trade between countries as long as it occurs in a coordinated way: after the change, relative unit costs of production remain unaltered because wages are affected in the same way in all countries so that the demand for tradable goods, whose level varies due to the income effects associated with the different wage growth regimes, continues to be distributed across countries as before.

This implies that, when the regime switch occurs in all countries at once, the trade-off arising from the twofold role of wages as a source of domestic aggregate demand and as a determinant of firms' international cost competitiveness, is solved. Not only a stronger wage dynamics favors the growth of domestic demand, improving sales expectations and stimulating production, but also the negative effect of wage expansions on the country's external balance, discussed in the previous section, is replaced by a positive feedback effect trough trade when wages vary in a coordinated way: since imports are rising everywhere, each country concurs to foster the rise of the demand for tradable goods produced by other countries. Conversely, a slowdown in wage growth depresses demand and firms' production levels, while also causing a generalized contraction of international trade.

[28] For this reason it now makes no sense to present the graph relative to the external position of countries, as the Net Foreign Asset Position of the Monetary Union is 0 by definition since it represents a closed economic system.

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At the same time, different wage growth patterns continue to exert the same effects on the supply side of the economy that we discussed in Sections 3.2 and 3.3, influencing firms' profit margins, the evolution of market structure, and hence the dynamics of R&D investment. Regimes which favor the growth of wages reduce firms' profit margins, in particular in the immediate aftermath of the change in the value of υ (left and center figure at the bottom of panel 6). This exacerbates the Schumpeterian selection process favoring the exit of less productive firms and a process of market concentration. As a consequence, average R&D investment increases, being concentrated on fewer and bigger firms. This, in turn, enhances technological progress (center and right figures in the third row of panel 6) and labor productivity growth both in the non-tradable and tradable sectors (right on the top of panel 6 and left side in the second row), partly counteracting the squeeze of profit margins caused by the rise of wages.

Conversely, wage moderation allows less productive firms to survive by exploiting the lower cost of labor. However, in a dynamic perspective, this leads to more fragmented industries. Being dispersed among many small producers, R&D investments tend to be less effective. Innovation dynamics and labor productivity growth slacken, this partially offsetting the initial effect on firms' unit costs and profit margins.

As a consequence of the enhanced growth patterns of demand and labor productivity, real GDP is markedly higher in the wage inflationary scenarios and lower in the wage moderation ones. The rise of output in the expansionary cases is such that the labor saving effect exerted by technological progress observed in the corresponding experiments focusing on individual countries (discussed in Section 3.2) fades out: the center figure on the top of panel 6 shows that unemployment is almost stable across scenarios. Conversely, the advantage in terms of lower unemployment brought by wage moderation in individual countries almost disappears when wage moderation is generalized, as a consequence of the fall in output levels.

The dynamics of prices in the non-tradable and tradable sectors (second and third plots in the second row of panel 6) show that part of workers additional purchasing power originated by the rise of wages translates in higher inflation rates, whereas wage moderation dampens the growth of prices. As a consequence of the effects exerted on real GDP, employment, and inflation, the effects of wage expansionary and wage moderation strategies on public finance are reversed with respect to the single country cases analyzed before: coordinated wage inflationary scenarios tend to be associated with lower, rather than higher, public debt-to-GDP ratios, while the opposite holds when countries 'agree' to dampen the growth of wages.

The results of this experiment seem to justify some skepticism about the efficacy and desirability of generalized wage moderation policies, while highlighting the possible mutual benefits originating from a coordinated expansionary strategy towards wages. Our artificial Monetary Union thus appears to be characterized by a 'wage-led' growth regime (Lavoie and Stockhammer, 2012), where a distribution more favorable to workers improves the economic performance.

The effects of coordinated wage strategies within our Monetary Union are not dissimilar from those we would obtain by applying the same strategies in a closed system. Indeed, wage-led growth regimes are often a property displayed by relatively closed economic systems. Obviously, the fact that our model abstracts from international trade and financial flows outside the Monetary Union, contributes to limit the scope of these results. In reality, countries having strong trade relationships outside the Union may still suffer a slack in their international performance as a consequence of a wage inflationary strategy, even if agreed with Union partners, while possibly benefiting from a wage moderation strategy which improves their cost competitiveness vis-à-vis countries outside the Union. Yet, there are two counter-arguments against this criticism: first, the Euro crisis has been mainly regarded as a matter of intra-EU imbalances *between* member countries, rather than with the rest of the world. Secondly, given that much of the trade and financial exchanges of European countries takes place with other European partners, the European Union as a whole can be considered as a relatively closed system at a first approximation.

The prevalence of a wage-led growth regime emerging from our simulation experiments seems to find a confirmation, for the European Union, in several empirical studies: Stockhammer and Sotiropoulos (2014) show that wage moderation and wage flexibility may work for small individual countries but it is likely the recipe for stagnation if generalized within a highly integrated global economy, since it neglects the role of wages in the demand formation. Conversely, an increase in the wage share in the Euro area as a whole would have expansionary effects (Stockhammer et al., 2009). On the same line, Onaran and Galanis (2012) estimate the effects on growth of a change in the wage share in the G20 countries using a post-Keynesian model and calculates the global multiplier effects of a simultaneous decline in the wage share. Given that most developed countries are found to be characterized by a wage-led growth regime, strategies of international competitiveness based on wage competition in the context of a highly integrated global economy are likely to be highly detrimental, whereas a coordinated macroeconomic and wage inflationary policy may help to correct global imbalances and foster growth. Similarly, Onaran and Obst (2016) finally estimate a multi-country demand-led growth model for the EU-15 countries which is then employed to show that a decrease in the share of wages in national income in isolation generates a slowdown in eleven countries, including all major economies, whereas beneficial effects are found only for Austria, Belgium, Denmark, and Ireland. However, a simultaneous decline of the wage share in all countries exerts negative effects on the growth in the EU-15 and supports the case of wage coordination.

3.5. Wage growth patterns, number of countries, and consumers' demand elasticity to prices

We propose two extensive sensitivity experiments to provide a further check of the robustness of the results discussed in Section 3.4.

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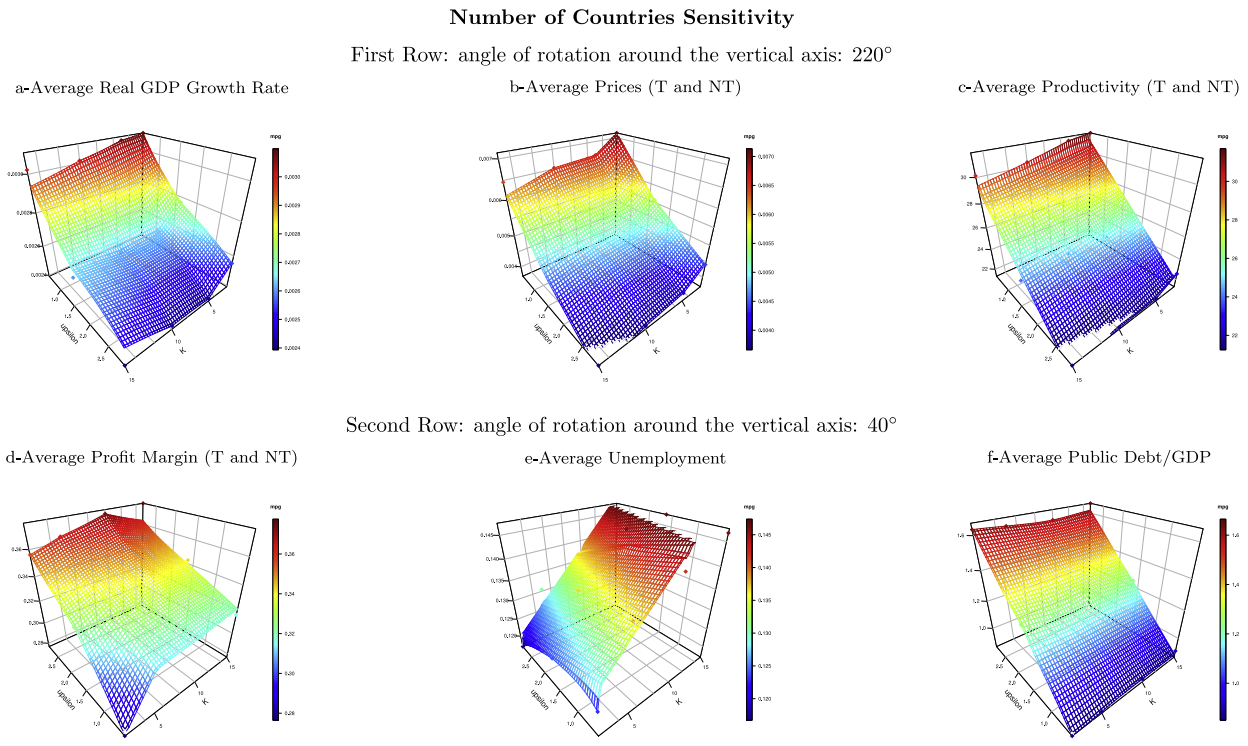

Fig. 7. Kriging-interpolated surfaces showing the effects of (coordinated) alternative wage growth patterns in a Monetary Union with 2, 5, 10, and 15 countries. The plots have been rotated for graphical reasons to allow the most appropriate visualization of results. The heading of each row of plots reports the angle of rotation around the vertical axis.

First, following Caiani et al. (2018a), we consider the case of a Monetary Union composed by a different number of countries[29]: by changing the number of countries involved in the simulations, the overall dimension of the Union and the extension of its common market for tradables are also modified. For this sensitivity we consider the cases of a Monetary Union composed of 2, 5, 10, and 15 countries.

Second, we re-executed the experiments of Section 3.4 by changing the way consumers weigh the price and distance of alternative goods when ranking potential suppliers. The heuristics employed for this sake stated that supplier i is preferred to supplier j if:

$$\frac{1}{d_{hi}^{\beta}}\frac{P_t}{p_{it}} > \frac{1}{d_{hj}^{\beta}}\frac{P_t}{p_{jt}}$$

When consumers weigh more price differentials the elasticity of their demand to prices is higher. If they give instead more importance to the distance between their location and the location identifying the varieties offered by firms, the elasticity of demand to prices is lower. Formally, these alternative configurations can be investigated by changing the value of the parameter β: the higher β, the lower the elasticity of demand to prices. Besides the baseline configuration $\beta = 2.0$, six other values of β were tested: 0.75, 1.0, 1.5, 2.5, 3.0, 4.0.

Panels 7 and 8 display the results of these two sensitivity experiments in a 3D format where the two horizontal axes display the combination of the parameters $\{\upsilon, K\}$ or $\{\upsilon, \beta\}$ employed in each experiment, and the vertical axis shows the corresponding Monte Carlo averages for a batch of key variables.[30] Each observation is represented as a filled square. In addition, the plots also display the surfaces obtained by interpolating these values with the Kriging interpolation method. This technique, originally developed in Geo-statistics, has been increasingly adopted as a meta-modeling tool in Economics, in order to approximate the behavior of 'big' models analyzed through computer experiments over a given parameter space. In particular, the Kriging method appears to be well suited for the carrying out of extensive sensitivity analysis of Agent Based models, as advocated by Salle and Yildizoglu (2014) who provide an exhaustive description of the technique and its possible applications in this field of study.[31]

[29] As mentioned in the text, a similar robustness check was also performed for the experiments considering the effects of a change of the wage growth pattern in single countries.

[30] For each configuration tested, 50 Monte Carlo replications have been executed.

[31] A similar application of the method can be also found in Caiani et al. (2018b).

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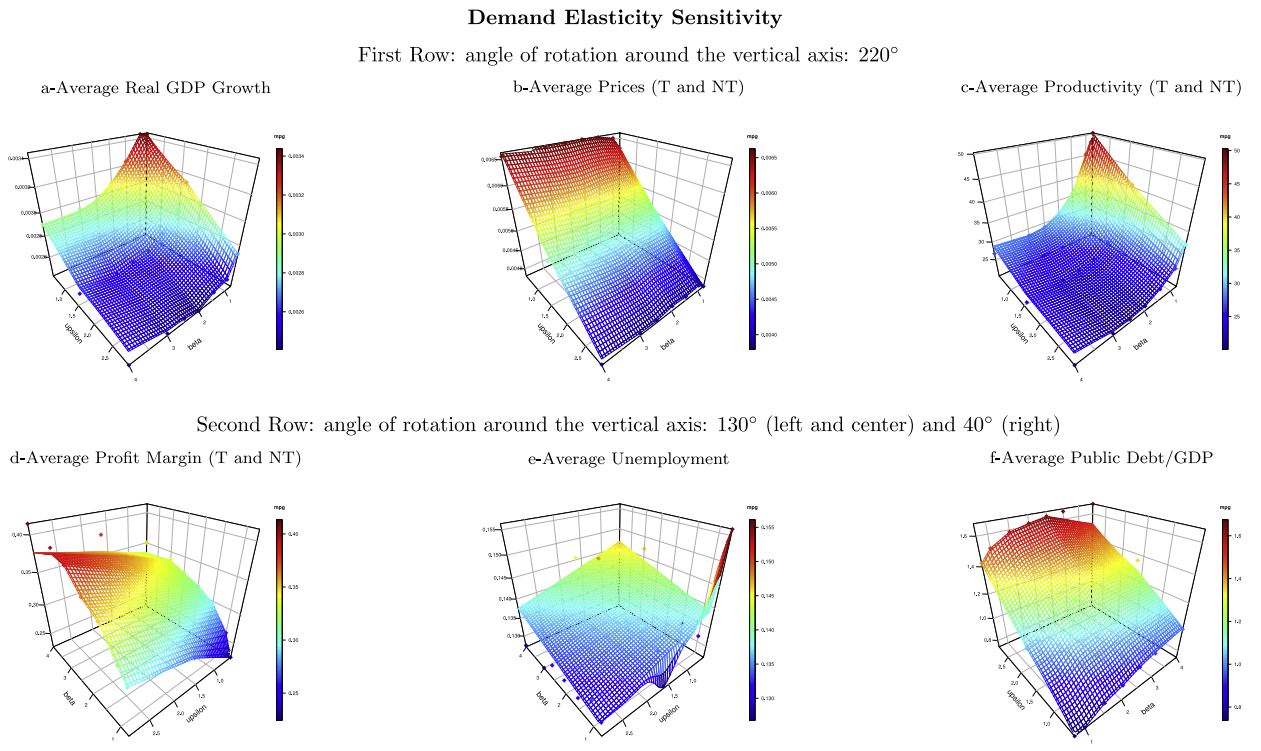

Fig. 8. Kriging-interpolated surfaces showing the effects of (coordinated) alternative wage growth patterns in a Monetary Union with 5 countries and with different demand elasticities to prices. The plots have been rotated for graphical reasons to allow the most appropriate visualization of results. The heading of each row of plots reports the angle of rotation around the vertical axis.

Figures in panel 7 display the results of the experiments carried out by changing the number of countries involved in the simulations, confirming the robustness of the insights gained from the experiments discussed in Section 3.4. Even though a different number of countries may affect the values of the indicators displayed in these plots, the impact of alternative wage growth patterns (identified by the values attributed to the parameter υ) is homogeneous across these scenarios: regardless the number of countries involved in the simulations, real GDP growth, labor productivity, and inflation are remarkably higher when countries follow a coordinated wage expansionary strategy (i.e. for lower values of υ), and lower when they follow a coordinated wage moderation strategy; the public debt-to-GDP ratio and firms' profit margin instead are lower for lower values of υ, and vice-versa. Finally, there is no clear relationship between alternative wage growth patterns and unemployment, as the changes in output and labor productivity growth rates tend to offset each other in affecting employment.

Conversely, the number of countries seems to play only a minor role on the evolution of the system as the levels of the variables plotted display only minor variations across scenarios characterized by the same value of υ.[32]

Figures in panel 8 display the results of the sensitivity experiments on consumers' demand elasticity. Once again, the robustness of the results discussed in Section 3.4 seems to be confirmed: lower values of υ are generally associated with higher real GDP growth rates, labor productivity, and inflation, and lower public debt/GDP ratios and profit margins. However, these results also show that the impact of alternative wage growth patterns on the dynamics of the system tend to be milder for higher value of β, corresponding to a lower sensitivity of demand to prices, whereas their effect becomes more pronounced for lower values of β, that is, when prices matter more for consumer consumption allocation decisions.

Furthermore, lower values of β are associated with greater values of real GDP and labor productivity, lower profit margins, slightly higher levels of unemployment, and lower public debt-GDP ratios. This can be explained by making again reference to the Schumpeterian selection process of firms discussed in the previous sections. Increasing consumers' demand sensitivity to price differentials exacerbates price competition between firms, resulting in lower prices and narrower profit margins. This, in turn, strengthens the selection process of firms: a higher sensitivity of demand to prices thus produces effects on the evolution of the tradable and non-tradable market structures similar to those observed in the case of a coordinated acceleration of wages, favoring the disappearance of less productive firms and a more effective allocation of R&D

[32] The only exception is represented by unemployment which tends to be slightly higher when increasing the number of countries. However, variations across these scenarios are tiny, ≈2.5% between the two extreme cases with 2 and 15 countries involved.

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investment, reinforcing innovation dynamics and labor productivity growth. Nevertheless, they differ in that the enhanced price competitiveness arising from lower values of β tends to dampen inflation, whereas the wage inflation exerted an upward pressure on prices. A higher sensitivity of demand to prices thus reinforces the effects of faster wage growth regimes on the supply side of the economy. On the contrary, a lower sensitivity partially neutralizes the evolutionary effects of a faster wage growth by reducing price competition between firms, allowing less productive firms to increase prices (under the pressure of rising unit costs) without incurring in the risk of seeing their market shares shrinking. This explains why scenarios with lower β are generally associated to greater real GDP and labor productivity growth, and why regimes which favor the growth of wages seem to be more effective when consumer have lower β. Finally, it is interesting to notice that despite lower β and lower υ generally lead to more concentrated market structures, surviving firms' profit margins in these scenarios are generally lower: in fact, the enhanced price competition between firms and the upward pressure of wages on their unit costs, which jointly contribute to squeeze profit margins, prevent surviving firms from gaining excessive rents from their oligopolistic market power.

4. Summary and refinements

In this paper we have analyzed and compared the effects of changes in the wage growth patterns of countries belonging to a Monetary Union. Experiments have considered both the case in which these changes take place in a single country and the case of a coordinated change occurring in all member countries at the same time. Our results suggest that, in all the scenarios explored, a change in the wage growth pattern not only affects the dynamics of demand, but also geenrates non-trivial effects on the supply side of the economy: in particular, scenarios more favorable to the growth of wages seem to reinforce firms' Schumpeterian selection process, pushing marginal firms out of the market and favoring the growth of more productive ones. This, in turn, produces positive effects on R&D investment allocation and firms' innovative performance, thereby fostering a faster growth of labor productivity. On the contrary, wage moderation scenarios allow less productive firms to survive, leading to market structures characterized by more firms having, on average, smaller dimension, thereby causing a more dispersed and less effective allocation of R&D investment. This effect is consistent with the theoretical insights and the empirical evidence provided by Kleinknecht (1998); Kleinknecht et al. (2014); Vergeer and Kleinknecht (2014) who find that deregulation aiming to dampen wage growth and to increase wage flexibility may be advantageous in the short run but is detrimental from a Schumpeterian perspective as it discourages R&D in product and process innovation, allowing less innovative firms to survive by exploiting the lower labor costs.

When the wage regime switch occurs in a single country, both wage moderation and wage inflation regimes give rise to a specular trade off between the external and fiscal stance of the country on the one hand, and the dynamics of other important macroeconomic indicators on the other: wage expansions tend to worsen the country external position, increase public debt-to-GDP ratios and are generally accompanied by a higher level of unemployment. However, in the long run, they also display a faster labor productivity growth which allows real GDP to catch up and possibly outperform other countries. Conversely, wage moderation in a single country allows to improve the Net Foreign Asset Position of the country and the fiscal stance of the government, and to lower unemployment. However, this latter effect is mainly due to a slowdown in the labor productivity dynamics which tends to weaken real GDP growth in the long run.

On the contrary, this trade-off fades out when countries agree to change the wage growth pattern in a simultaneous and coordinated way, thereby leaving their relative competitive position unaltered. In this case, a coordinated wage expansionary strategy seems capable of improving real GDP growth, innovation dynamics, labor productivity growth, and public debt/GDP levels. The rise of real aggregate demand is such to offset the possible labor-saving effect of the enhanced innovative performance, leaving unemployment levels almost unaffected. Generalized wage moderation tends to produce specular result, hampering the economic dynamics of the system. These results, being consistent with the predominance of a wage-led growth regime in the Monetary Union, thus seems to make a case for a coordinated policy of wage increases across core and peripheral countries as a possible way out of the recession which hit European economies after the global financial turmoil and the Euro crisis. This result is consistent with the theoretical arguments and the empirical evidence provided by Onaran and Galanis (2012); Onaran and Obst (2016); Stockhammer et al. (2009); Stockhammer and Sotiropoulos (2014) who argue in favor of coordinated wage increases, showing that wage moderation can work only under particular circumstances while it is likely to hinder economic growth if generalized.

The robustness of these results has been checked and confirmed under scenarios characterized by a different number of countries. Finally, we also analyzed the impact of coordinated changes in the wage growth patterns in relation to different specifications of the rule employed by consumers to rank potential suppliers: results suggest that a higher sensitivity of consumers' demand to price differentials not only dampen inflation but also exacerbates the Schumpeterian selection process of firms in a way similar to that emerging in wage expansionary scenarios. Therefore, the beneficial effects of a coordinated wage expansionary strategy, as well as the detrimental effects of a generalized wage moderation regime, are reinforced when consumers give more importance to price differentials, and softened in the opposite case.

Despite our results seem to be robust across the scenarios tested, we are well aware that some caution is advisable given the simplified nature of the model.

First, the model does not consider investment in physical capital and thus lacks a fundamental component of real GDP. As a consequence, it focuses on incremental patterns of innovation resulting in a disembodied technological progress which progressively increases labor productivity. However, it would be worth exploring alternative characterizations of technolog-

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ical progress, considering for example a wave of radical innovations, or technological progress embodied in new capital vintages.

Finally, the financial side of the model is still oversimplified: for example, it completely neglects cross-border equity investment by households and employs almost-random matching procedures on the international credit and bond markets. As a consequence, the role of financial factors is underestimated compared to trade-related factors. In future refinements of the model efforts will then be dedicated to improve these aspects in order to give a better account of international financial flows which, as discussed in the Section 1.1, have played a crucial role in driving the evolution and mutual relationships of European economies, with strong implications for the resilience of the EMU.

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Appendix A. Baseline Setup

Table 2

Table 2
Parameters.

K: Number of countries	5	μ_2: Minimal reserve requirement parameter	0.1
H: Number of Households	500	ι_l: Loan probability parameter	0.5
l^S: Workers' labor supply	1.0	χ: Loan interest parameter	0.003
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	0.4	ξ: Taylor rule adjustment speed parameter	0.8
c_y: Propensity to consume out of income	0.9	$\xi^{\Delta P}$: Taylor rule sensitivity to inflation	2
c_D: Propensity to consume out of wealth	0.1	$\overline{\Delta P}$: 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	0.35
β: Hotelling circle parameter	2.0	tau_{max}: Maximum tax rate	0.45
λ: Liquidity preference parameter	0.1	g_{min}: Minimum G/GDP	0.4
θ: Share of sales as inventories	0.2	g_{max}: Maximum G/GDP	0.6
γ: R&D expenditure parameter	0.04	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	20	G: Initial real value of public spending	200

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Table 3
Baseline summary
Average simulated and empirical macro-variables in percentage values. Simulated data are averages values across countries and across the 50 Monte Carlo simulation runs. The standard errors of the country averages across Monte Carlo simulations are also displayed in brackets. Quarterly rates have been transformed in annual rates for comparative purposes. Nominal GDP was computed as total sales, evaluated at their selling prices, plus the variation of inventories, evaluated, in accordance with standard accounting, at their unit cost of production. Real GDP is obtained by dividing nominal GDP for the average price of domestically produced goods and services. Empirical indicators refer to the Euro Area (19 countries) and are computed on annual data. Data are taken from the Eurostat when not differently specified. The time-span ranges from 1999 (i.e. the launch of the Euro) and 2016. However, we divided the reference time-span into two sections (1999–2007 and 2008–2016) so to isolate the period affected by the great recession and by the prolonged Euro-crisis. Real GDP growth rates follow the standard definition. The labor productivity for the total economy refers to real labor productivity per person employed computed as gross domestic product, constant prices, divided by total employment, all industries, in persons. Labor productivity for the manufacturing sector (OECD data) is gross value added per person employed, constant prices. Inflation is the annual average rate of change of the HCPI. Unemployment is computed as a percentage of the active population. Public debt is the consolidated gross debt of the general government. Public deficit is the net borrowing of the general government. Private debt is the (consolidated) stock of liabilities held by non-financial corporations (S11), households, and non-profit institutions serving households (S14-S15). The instruments taken into account to compile private sector debt are debt securities (F3) and loans (F4). Exports and imports indicate exports and imports of goods and services. Public expenditure is the total expenditure of the general government. R&D investment is intramural R&D expenditure (GERD) by all sectors. Household investment is gross fixed capital formation by households and non-profit institutions serving households.

Variable	Simulations 2 countries	5 countries	10 countries	15 countries	Euro area 1999-2007	Euro area 2007-2016
Real GDP growth	1.2	1.1	1.1	1.1	2.3	0.4
	(0.054)	(0.054)	(0.047)	(0.050)		
Real labor productivity growth	1.2	1.1	1.1	1.09	Total economy: 0.9	0.4
	(0.054)	(0.055)	(0.047)	(0.050)	Manufacturing only: 3.3	1.8
Inflation	2.3	2.2	2.1	2.1	2.2***	1.4
	(0.090)	(0.074)	(0.110)	(0.047)		
Unemployment	12.6	14.0	14.5	14.6	8.8	10.4
	(1.13)	(0.818)	(0.596)	(0.484)		
Public Debt/GDP	124.4	122.2	122.6	122.9	68.3	86.0
	(18.215)	(29.627)	(33.600)	(33.151)		
Public Deficit/GDP	1.0	1.1	1.0	1.0	2.0	3.5
	(0.291)	(0.162)	(0.291)	(0.279)		
Private Debt/GDP	138.6	127.7	123.79	123.43	122.1**	142.2
	(11.571)	(9.301)	(6.672)	(6.556)		
Exports/GDP	18.5	29.5	33.1	34.28	35.4	42.3
	(0.581)	(0.286)	(0.199)	(0.349)		
Imports/GDP	18.5	39.5	33.1	34.33	33.8	39.5
	(0.612)	(0.581)	(0.212)	(0.349)		
Public Expenditure/GDP	45.4	46.5	46.8	46.9	46.6	49.1
	(1.010)	(0.788)	(0.583)	(0.539)		
R&D Investment/GDP	2.8	2.7	2.7	2.7	1.8*	2.1
	(0.066)	(0.051)	(0.027)	(0.039)		
Household investment to GDP ratio	8.7	8.7	8.6	8.6	6.9	5.8
	(0.135)	(1.001)	(0.087)	(0.080)		

* data availability for the EA (19 country) starts from 2000; ** data for the EA (19 country) starts for the EA (19 country) from 2001; *** data for the EA (19 country) starts from 2002

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