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Open Science vs. Mission-oriented Policies and the Long-run Dynamics of Integrated Economies: An Agent-based Model with a Kaldorian Flavour

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Abstract

This paper offers a contribution to the literature on science policies and on the possible trade-off that might arise between broad spectrum science-technology policies and mission-oriented programs. We develop a multi-country, multi-sectoral agent-based model of economic dynamics with endogenous structural change that represents a small-scale monetary union. Findings are threefold. Firstly, science policies from national governments, even when *symmetric*, act as a source of growth divergence across countries. Secondly, even if economic growth is largely driven by the sectors with absolute advantages, having at least a little flow of open science investments is sufficient for the other industries to survive and innovate, hence preserving the bio-diversity of the economic structure. Thirdly, science policy alone is a sufficient means to break monopolistic tendencies, trigger competition and reduce income inequality. Still, such results are conditioned to the flow of open science. Yet, the working of the model suggests that supply-side science policies should be paired with demand-side policies for the wide re-organisation of consumption habits, if grand societal challenges are to be met.

JEL Classification: Science policies, Structural and technical change, Economic growth.
Keywords: E11, E32, O33, O41.

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Contents

1 Introduction

In early 1942, the US administration appointed the Major General Leslie Groves and the nuclear physicist, Prof. Robert Oppenheimer to recruit and coordinate a vast group of scientists to the development of the atom bomb. Thus began the Manhattan Project, the first, important mission-oriented program. The challenges, the endeavours and the scientific success out of the Project inspired many Western governments to extend and implement the range of programs with similar organisations and capabilities.
The European Commission (2018c, p. 2) defines *mission-oriented* initiatives as "large-scale intervention aiming for a clearly defined mission (i.e. goal or solution) to be achieved". Under the aegis of the public sector, such programs concern ambitious, exploratory, cross-disciplinary activities to address societal and technological targets, from the development of the computer industry (Mowery and Langlois 1996) and the Apollo Program (Mazzucato 2011) across the Fifties and the Sixties, up to contemporary challenges, i.e., energy and climate change (Anadón 2012, Mowery, Nelson and Martin 2010). At the same time, governments spend considerable funds on basic research in universities and institutes, and there is extensive evidence that basic research provides direct as well as indirect economic benefits (Ergas 1987, Salter and Martin 2001).

However, the analysis of trade-off between broad spectrum science and technology (S&T) policies and the research with a mission orientation is still scant in the economic literature.[1] Even scantier is the analysis of the impacts of such policies and their plausible trade-off on economic growth, structural change, and specialisation trajectories.
This paper is a step forward to fill that gap. We develop a multi-sectoral agent-based model of endogenous structural change, composed of countries joined by a Monetary Union. In this framework, besides the population of firms, workers and consumers, the national governments enter the economy through investments in research and innovation. They devote a share of GDP to finance either broad spectrum S&T policies or mission-oriented programs to target specific sectors and objectives.
Among the several results, we firstly suggest that the sole intervention of the government in the economy by means of science policies is a sufficient condition to experience growth divergence mechanisms. This is far more evident when observing labour productivity dynamics: even if countries pursue *symmetric* science policies, their very existence fuels a strong and persistent divergence in growth. Secondly, we want to underline the important role played by open-science policies. Even though productivity differentials exist and persist across industries and countries, such policies make sectoral gains more concentrated around a common average trajectory. Conversely, sectoral productivity differentials are

[1] We use terms as *open science*, *public research*, *broad spectrum S&T* policies interchangeably.

enlarged by rising shares of mission-oriented projects in government expenditure. In this case, even if economic growth is largely driven by sectors with absolute technological advantages, a flow, however tiny, of open-science investments allows other, weaker industries to survive and innovate. Thirdly, science policy alone manages to break and counteract monopolistic tendencies, triggering competition and country's de-specialisation. Still, the strength of this mechanism depends on the allocation of resources between broad spectrum policies and mission-oriented programs.
Nevertheless, science policies do not affect the structure of consumption and households habits. Therefore, to be effective in dealing with societal challenges, they should be coupled with demand-side policies, governance, and consumer's involvement, as recently suggested by European Commission (2018a,e). All these results are also strengthened by the ability of our model to match a wide spectrum of stylised facts concerning economic growth and specialisation patterns at country, industry and firm level.

The article is organised as follows: Section 2 reviews the relevant literature; Section 3 describes the theoretical setting; Section 4 presents the results out of the baseline scenario; Section 5 develops the experiments on *symmetric* science policies and discusses the results; Section 6 concludes and offers some implications for policy and future research. The Appendix offers further baseline statistics and *asymmetric* science policies.

2 Relation with the literature

We contribute to several strands of research. First and foremost, we contribute to the understanding of the impacts of S&T policies on macroeconomic dynamics. In particular, the role of governments in funding research is at the core of the economic analysis back to the late Fifties. On the one hand, the neoclassical arguments *à la* Nelson (1959) and Arrow (1962) reported to the difficulties of appropriating the benefits out of research with the consequent "market failure" in which private firms underinvest in innovative search: from which a general plea for public funds. On the other hand, there is all the bulk of evolutionary literature on innovation and technical change *à la* Dosi and Nelson (2010), Mazzucato (2016), Metcalfe (1995), Rosenberg (1982), according to which direct and indirect innovation policies require and imply an active role of national governments to shape technological landscapes, to shape search regimes, and to take risks that the private sector does not want to absorb in a first stance (Dosi, Lamperti, Mazzucato, Napoletano and Roventini 2023). The evolutionary theory does not look at governments as solution to a market failure per se, but as the source for the enhancement of competitive performance and the promotion of structural change (Metcalfe 1995). To paraphrase Rosenberg (2010), scientific knowledge is not a costless good available to anybody, but it is embodied in specific researchers and institutional networks, and to master it investments are required. Therefore, corporations prefer entering a new market only after the great bulk of uncertainty has already been handled by the public sector (Cimoli, Dosi and Stiglitz 2009, ch. 2). In this case, government innovation policies create new technologies, new markets and new industries (Foray, Mowery and Nelson 2012, Mowery 2009).[2]

Close to the evolutionary perspective in its analysis of the relation between economic growth, development, and technical change, is the *technology gap* approach *à la* Abramovitz (1986), Fagerberg (1994), Gerschenkron (1962). This literature starts from the observation that differences in technological levels and trends characterize the international economic system. These differentials are at the core of economic growth divergences between *leaders*, i.e. countries standing at the technological frontier, and *latecomers*, i.e. countries on a lower technological level. The possibility for the latter to catch up with the leaders depends on their ability to mobilise resources for transforming social, institutional and economic structures (Fagerberg 1987). However, this is possible if and only if latecomers succeed in developing *social capabilities* in the forms of competencies at firm level, high-quality educational systems and efficient financial markets (Abramovitz 1986).

Among this very large literature, this work shares some commonalities with Foray and Llerena (1996) and Dosi et al. (2023). Foray and Llerena (1996) revisit Aoki (1986) to link the level of the information structure to the degree of centralisation of decision. Crucial determinants were found in the learning capabilities of the firms and the government response time. They compared two different policy scenarios, i.e., mission-oriented and diffusion policies, whose design is very similar in scope to ours.

Dosi et al. (2023) study the impact on alternative innovation policies on both the short and long-run performance of an economy. In particular, that paper depicts an economy in which the public sector intervenes through the creation of a National Research Lab and a public capital-good enterprise, whose aim consists of disseminating knowledge and creating avenues for radical innovations. This policy setting is then compared to a more traditional one in which the State provides R&D subsidies or investment tax discounts. The overall findings support the idea that public research bodies improve economic performance more than traditional pigouvian solutions: the outcome is a higher growth potential along with a public deficit kept under control. Our paper slightly differs in the schedule of the experiments, since Dosi et al. (2023) do not analyse the trade-off between broad spectrum and

[2] By the way, a body of research that relies on recent microeconometric evidence shows that corporate practitioners draw a lot upon research performed in domestic universities and other public organisations as source of knowledge to back their innovative activity. More on that in Arora, Belenzon and Patacconi (2015), Arundel and Geuna (2004), Bianchini and Llerena (2016), Bianchini, Llerena and Patsali (2019), Narin, Hamilton and Olivastro (1997). Cf. Beise and Stahl (1999) for a somewhat contrasting viewpoint.

mission-oriented policies, and focus on a closed economy only. Our framework, instead, takes these issues into account and provide the conditions under which a too-large commitment to mission-oriented programs can foster productivity growth divergences both across countries and across sectors. Moreover, our article pinpoints to the crucial role of open science in triggering competition, reducing productivity differentials and income inequality.

Finally, this paper contributes to the literature on growth dynamics, structural change, and coordination issues *à la* Allen (2001), Dosi, Fabiani, Aversi and Meacci (1994), Dosi, Freeman and Fabiani (1994), List (1856). A first group of works develops around Ciarli, Lorentz, Valente and Savona (2019), Lorentz (2015a,b). Their theoretical setting, very similar to ours, shows that the main drivers for specialisation also generates growth rate differences among economies. When emerging out of the heterogeneity of technical change at the microeconomic level, specialisation engenders cross-country growth rate differences that yet are only transitory. Conversely, permanent divergences in economic and productivity growth are fuelled by demand factors as represented by heterogeneous income elasticities (Lorentz 2015a). This study presents similar results in the benchmark model, but it leads to different conclusions when turning to S&T policies, which are quite able to engender persistent growth divergences across countries in terms of GDP and labour productivity by solely letting the State intervene in the economic sphere.
The model clearly belongs also to the literature on open-economy agent-based models which tackle regional as well as monetary-unions issues (Caiani and Catullo 2023, Caiani, Catullo and Gallegati 2018, Dawid, Harting and Neugart 2014). For instance, using a two-region macroeconomic model, Dawid et al. (2014) provide insights on short-to-long period outcomes of policies fostering the improvement of human capital and the adoption of new technologies across richer and poorer regions. The labour market is the key variable for when it is fully integrated between regions, such policies enhance divergence patterns and make the rich ever richer and poor regions ever poorer. Conversely, Caiani et al. (2018) analyse the relationship between fiscal policies, wage dynamics, growth performance, and debt sustainability in a framework that closely resembles the European Monetary Union. Our work, even though it does not account for debt-sustainability issues or labour-market dynamics, depicts the working of an integrated economic system and is in agreement with the mentioned papers in underlining the important call for coordinated and redistributive policies at the supranational perspective.

3 An evolutionary model of structural change with a Kaldorian flavour

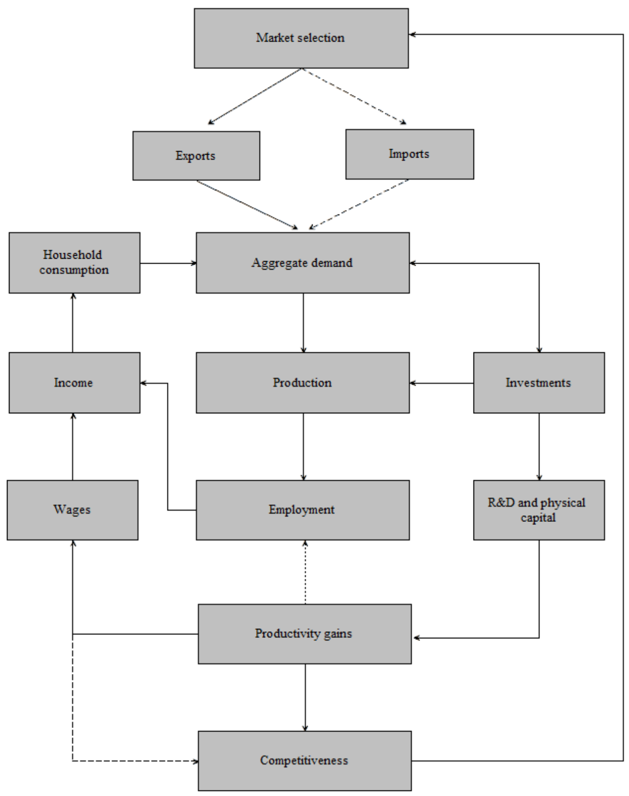
We propose here a multi-country, multi-sectoral model of economic dynamics with endogenous structural changes. In line with the evolutionary literature, we build the model around three populations of agents: private firms, households and a public sector. These populations interact within the country they are located as well as between countries. The aggregation of these population dynamics determines the macro-level dynamics of the system.
Private firms produce differentiated goods and services for a single industrial sector (i.e., food, textile, transportation and so on). These goods and services are consumed by both domestic and foreign households. To produce, private firms develop their own production capacities, through their investments, improve the efficiency of their production process and the characteristics of their products through their R&D activity, and provide domestic households with income through the payment of wages.
Households provide the workforce and consume the goods and services provided by either domestic or foreign private firms. The distribution of expenditure shares among industrial sectors (i.e., groups of goods and services) follows both the dynamics of income as distributed by firms and the characteristics of the goods and services provided by firms. Households are divided into consumer/worker groups sharing a similar level of income and a common structure of expenditures. The structure of expenditures is defined by an Engel-curve-like mechanism: as income grows, the expenditure levels follow the curve, while changes in the characteristics of goods and services modify the shape of the curve.
All of the countries share a common currency. The interaction among countries are therefore limited to trade in goods and services. In this respect, the model accounts for the dynamics of a single currency system in the line with the European Monetary Union. The last population of agents is composed by country-specific public sectors. The aim of this paper is to analyse the effect of various targeted S&T policies (i.e., mission-oriented policies) versus public spending in broad and fundamental research in sustaining leadership, or favouring catching-up.

The model is evolutionary micro-founded in that both technological and structural changes result from evolutionary micro-processes. Innovations are the engine for both productivity gains and changes in the characteristics of goods and services, themselves source for changes in the structure of expenditures. The impact of innovations on the dynamics of the system are catalysed by the market selection mechanisms and triggered by individual behaviours. First, productivity gains, allowing to sustain competitiveness, result from firms innovative behaviour. This component of the model is directly inspired by the neo-

Schumpeterian evolutionary literature on technological change, and largely draws upon previous works (Llerena and Lorentz 2004, Lorentz 2018, Savona and Lorentz 2006). Second, changes in the structure of aggregate demand are related to changes in the satiation of households expenditures resulting from product innovations introduced by firms. In this respect, the model aims at introducing the mechanisms found in behavioural foundations of Engel curves that links first satiation to the characteristics of goods, and product innovation resulting in changes in these characteristics as a way for firms to escape from satiation (Ciarli and Lorentz 2010, Lorentz, Ciarli, Savona and Valente 2016, Witt 2010).

The model includes a Kaldorian flavour in the sense that the dynamics at work are demand driven, and the allocation of income defines and transforms the structure of expenditures, shaping the industrial structure of the economies. The dynamics of demand shape the resources available for firms to improve their efficiency and gain in competitiveness. Furthermore, the efficiency and competitiveness gains of firms, and of the economies a whole, on international market fosters the expansion of demand. The interplay of these three mechanisms allow for a Kaldorian cumulative causation dynamics. Following Kaldor (1966), the model revolves around the idea that the structure of domestic demand catalyses the growth impulses generated by external demand, generating economic growth. Exports growth is sustained by gains in competitiveness generated by technological change, themselves fostered by the increases in resources generated by economic growth. The combination of those mechanisms insure self-sustained growth.

Formally the model is structured as follows. We consider a set of C economies integrated in an single currency economic system through trade relations. An economy $c \in [1;C]$, is referred to using the index c. From the perspective of the economy c, the variables indexed $\bar{c}$ refer to foreign economies. Our economic system counts J industrial sectors of activity. Each economy c can produce and consume goods and services from each sector $j \in [1;J]$. Each of the economy c counts a population of I firms as active in each of the J sectors. A firm $i \in [1;I]$, producing in sector j and based in the economy c is referred to with the subscripts i,j,c. The entire economic system then counts C economies, J sectors, and $C * J * I$ firms. In each economy c, households are classified in H consumer/worker groups. A group of consumer h gathers all the workers of the tier $k = h$ of all the I firms in all the J industries. The total number of households groups in an economy c is given by the highest number of worker tier Λ found among the I firms in the J sectors of an economy c. The index t refers to the time step. Fig. 1 portrays the model.



Note: continuous and dashed lines point to positive and negative effects, respectively.

Figure 1. Chart of the model

3.1 Private firms: production and Innovation

This subsection is devoted to the description of the micro-dynamic functioning of the model from the side of the private firms. We consider that private firms, and their behaviours, define the path of technical change, throughout their R&D behaviours, and the economy's production capacity throughout their investment in capital stock. Both then shape the economy's competitiveness on international markets.

We consider a population of bounded rational firms, heterogeneous in both the efficiency of their production capacity (i.e., labour productivity) and the characteristics of the goods or services they provide (i.e., satiability level). The mutations in both factors result from the behaviour of firms: (i) technical change emerges at the firm level as a twofold process: firms develop new production processes through their R&D activity and these require investments in capital to be exploited in building-up the firms production capacity; (ii) product innovation, developed through their R&D activity, modifies the nature of the goods or services produced, affecting the attractiveness of the latter to the consumer (i.e., satiability). The latter process relies on both the firm's R&D spendings as well as the results from targeted, as well as fundamental research spendings by the public sector. Satisfying the domestic and foreign demand provides firms with the financial resources to undertake investment activities.

3.1.1 Defining firms characteristics

The production process of each firm is represented at time t by a constant returns to scale production function with labour as a unique production factor. Capital is accumulated to build the production capacity, defining the productivity level of labour. Formally, the production function is represented as follows:

$$Q_{i,j,c,t} = A_{i,j,c,t-1} \cdot L_{1,i,j,c,t} \tag{1}$$

in which $Q_{i,j,c,t}$ is the output produced by the firm i in the sector j of the country c at time t; $A_{i,j,c,t-1}$ represents labour productivity level embodied in the production capacities accumulated by the end of period $t-1$ and available to be used in period t; $L_{1,i,j,c,t}$ is the labour force employed in the production process at time t.

The unit of output ($Y_{i,j,c,t}$) to be produced by the firm is defined by the share of effective demand directed at the firm at time t. The effective demand for a given sector j in a country c ($Y_{j,c,t}$) is determined at the macro-economic level while the amount of effective demand allocated to each firm i of this sector j in a country c is computed as a share of sector j demand given by their relative market share ($\frac{z_{i,j,c,t}}{z_{j,c,t}}$):

$$Q_{i,j,c,t} = \frac{Y_{i,j,c,t}}{p_{i,j,c,t-1}} = \frac{z_{i,j,c,t}}{z_{j,c,t}} \cdot \frac{Y_{j,c,t}}{p_{i,j,c,t-1}}$$

where $p_{i,j,c,t-1}$ corresponds to the price charged by the firm during the period t and set at the end of $t-1$.

Given the production capacity accumulated by a firm i, the level of employment necessary for production can be expressed as a function of the share of effective demand directed at the firm i:

$$L_{1,i,j,t} = \frac{1}{A_{i,j,t-1}} \cdot Q_{i,j,c,t} = \frac{z_{i,j,c,t}}{z_{j,c,t}} \cdot \frac{Y_{j,c,t}}{A_{i,j,t-1} \cdot p_{i,j,c,t-1}} \tag{2}$$

We follow the framework developed in Ciarli, Lorentz, Savona and Valente (2010), that draws upon Simon (1957), Lydall (1959a,b), Rosen (1981, 1982) and further extensions of it (Abowd, Kramarz and Margolis 1999, Prescott 2003, Waldman 1984) to represent the organisational structure of firms. According to this literature, firm size, number and complexity of hierarchical organisational layers internal to the enterprise (i.e., the proportion of executives and workers) affect the structure of earnings. On the top of the layer of workers affected to the production of goods or services ($L_{1,i,j,t}$), the firms need a layer of *executives* to manage every group of ν employees. This second layer of employees require a third layer of executives for every group of ν employees in the second layer. This third layer of employees requires a fourth layer for every group of ν employees and so on. The number of required layers defines the organisational complexity required to produce in this firm. The number of employees in each of the layer can formally be given as a function of $L_{1,i,j,t}$:

$$\begin{aligned}
L_{2,i,j,c,t} &= \frac{L_{1,i,j,c,t}}{\nu} = \frac{1}{\nu} \cdot \frac{Q_{i,j,c,t}}{A_{i,j,c,t-1}} \\
L_{3,i,j,c,t} &= \frac{L_{2,i,j,c,t}}{\nu} = \frac{1}{\nu^2} \cdot \frac{Q_{i,j,c,t}}{A_{i,j,c,t-1}} \\
&\vdots \\
L_{k,i,j,c,t} &= \frac{L_{k-1,i,j,c,t}}{\nu} = \frac{1}{\nu^{k-1}} \cdot \frac{Q_{i,j,c,t}}{A_{i,j,c,t-1}} \\
&\vdots \\
L_{\Lambda,i,j,c,t} &= \frac{L_{\Lambda-1,i,j,c,t}}{\nu} = \frac{1}{\nu^{\Lambda-1}} \cdot \frac{Q_{i,j,c,t}}{A_{i,j,c,t-1}}
\end{aligned} \tag{3}$$

where Λ is a fixed parameter defining the total number of layers required to manage the firm. The total number of employees ($L_{i,j,t}$) is given by the sum of all the layers of employees in the firm:

$$L_{i,j,t} = \sum_{k=1}^{\Lambda} L_{k,i,j,t} = \frac{Q_{i,j,c,t}}{A_{i,j,t-1}} \cdot \sum_{k=1}^{\Lambda} \frac{1}{\nu^{k-1}}. \tag{4}$$

The latter can be expressed as a function of the effective demand addressed to the firm:

$$L_{i,j,t} = \frac{z_{i,j,c,t}}{z_{j,c,t}} \cdot \frac{Y_{j,c,t}}{A_{i,j,t-1} p_{i,j,c,t-1}} \cdot \sum_{k=1}^{\Lambda} \frac{1}{\nu^{k-1}} \tag{5}$$

In the end, labour capacity is determined only by first tier workers and their productivity. We implicitly assume that a firm finds its best organisational configuration given the number of first tier workers, and given the organisational structure proxied by ν.
The wages paid to each tier of workers constitute the sole production costs of the firm. The wage level of each layers captures the income differences along the hierarchical structure. The first tier of workers sees its wage ($w_{1,i,j,t}$) set at the industry level. The wage level ($w_{j,t-1}$) results from sectoral level negotiations taking place during the period $t-1$ to be applied by firms at time t:

$$w_{1,i,j,t} = w_{j,t-1} \tag{6}$$

As we move upstream in the organisational hierarchy, the wage increases by a fixed tier multiplier b, which determines the skewness in the wage distribution, in line with Simon (1957) and Lydall (1959a,b).

$$\begin{aligned} w_{2,i,j,t} &= b \cdot w_{1,i,j,t} = b w_{j,t-1} \\ w_{3,i,j,t} &= b \cdot w_{2,i,j,t} = b^2 w_{j,t-1} \\ &\vdots \\ w_{\Lambda,i,j,t} &= b^{\Lambda-1} \cdot w_{j,t-1}. \end{aligned} \tag{7}$$

The total wage bill for the firm at time t is a function of effective demand:

$$\sum_{k=1}^{\Lambda} w_{k,i,j,t} \cdot L_{k,i,j,t} = \sum_{k=1}^{\Lambda} \left(\frac{b}{\nu}\right)^{k-1} \frac{w_{j,t-1}}{A_{i,j,t-1}} \cdot \frac{z_{i,j,c,t}}{z_{j,c,t}} \cdot \frac{Y_{j,c,t}}{p_{i,j,c,t-1}} \tag{8}$$

Firms set their prices at the end of the current period, applying a mark-up to their current unit costs, to be applied for the coming period. This mark-up (μ_j) is applied to the labour cost linked to the production process. The firm's price can be represented as follows:

$$p_{i,j,c,t} = \left(1+\mu_j\right) \cdot \frac{\sum_{k=1}^{\Lambda} w_{k,i,j,t} \cdot L_{k,i,j,t}}{Q_{i,j,c,t}} \tag{9}$$

where $p_{i,j,c,t}$ is the price set by firm i at time t and μ_j is the mark-up coefficient.
Substituting the number of unit produced by effective demand, the price level set by the firm results:

$$p_{i,j,c,t} = \left(1+\mu_j\right) \cdot \frac{w_{j,t-1}}{A_{i,j,t-1}} \cdot \sum_{k=1}^{\Lambda} \left(\frac{b}{\nu}\right)^{k-1} \tag{10}$$

The current level of profits earned by the firm can be computed as a function of the effective demand addressed to the firm:

$$\pi_{i,j,c,t} = p_{i,j,c,t} \cdot Q_{i,j,c,t} - \sum_{k=1}^{\Lambda} w_{k,i,j,c,t} \cdot L_{k,i,j,c,t}$$

$$\pi_{i,j,c,t} = \frac{z_{i,j,c,t}}{z_{j,c,t}} \cdot Y_{j,c,t} \cdot \left(1 - \frac{w_{j,t-1}}{A_{i,j,t-1} \cdot p_{i,j,c,t-1}} \cdot \sum_{k=1}^{\Lambda} \left(\frac{b}{\nu}\right)^{k-1}\right) \tag{11}$$

The profit earned by each firm depends on both the behaviour of the firm, in building and improving its production capacity as well as sectoral factors, such as wage negotiation, and market selection, as well as macro-economic factors such as effective demand and international competition. These profits represent the sole financial resources for investments.

3.1.2 Investment decisions

Firms use resources accumulated selling their production to build up and improve their capacity, and the characteristics of the goods or services they sell. The firms build their production capacity accumulating capital goods that they develop for production. Each capital good embodies a level of productivity. The labour productivity level of the firm for the production layer of workers results from the aggregation of the levels of productivity embodied in each capital good, weighted by the amount invested in exploiting this capital in building the production capacity:

$$A_{i,j,c,t} = \frac{I_{i,j,c,t}}{\sum_{\tau=1}^{t} I_{i,j,c,\tau}} \cdot a_{i,j,c,t-1} + \left(1 - \frac{I_{i,j,c,t}}{\sum_{\tau=1}^{t} I_{i,j,c,\tau}}\right) \cdot A_{i,j,c,t-1} \tag{12}$$

in which $a_{i,j,c,t-1}$ represents the labour productivity embodied in the capital good developed by the firm i during the period $t-1$. $I_{i,j,c,t}$ represents the level of investment in capital goods of the firm.

Each capital good is developed in-house by firms and then introduced in their production technologies. In other words, firms are integrated. This process is decomposed in two phases. First, firms explore and develop new capital goods. This phase takes place within the R&D activity. The second stage consists of introducing the outcome of the R&D activity within the production process. This stage is costly and requires firms to invest in the exploitation of the latest capital good vintage. The level of investment determines the relative importance of the latest capital goods in the production process and determines the actual productivity gains.

Firms also have to develop the characteristics, or quality index of their product: they first invest in capital goods, in order to gain from the already developed vintages, and then invest in R&D. The R&D investments are then shared between the development of capital goods and attempts to improve the quality index of the product of the firm. These distinct investments are subject to the firms financial constraint. Firms' only resources for investments are their profits. More profitable firms are more inclined to invest and therefore to improve their production capacities and their competitiveness.

Investments in capital goods correspond to a share $\iota_{i,j,c}$ of firms' resources. Given the financial constraint the investment level in capital good is formally represented as follows:

$$I_{i,j,c,t} = \min\left\{\iota_{i,j,c} \cdot Y_{i,j,c,t}; \Pi_{i,j,c,t-1} + \pi_{i,j,c,t}\right\} \tag{13}$$

A share $\varrho_{i,j,c}$ of the firm's resources are then devoted to the investments in R&D. For the sake of simplicity, these R&D investments are assigned indifferently to the development of the production capacity or process innovation, or to the research leading to product innovation, these are respectively formalised as follows:

$$R_{i,j,c,t} = \min\left\{\varrho_{i,j,c} \cdot Y_{i,j,c,t}; \Pi_{i,j,c,t-1} + \pi_{i,j,c,t} - I_{i,j,c,t}\right\} \tag{14}$$

Both investments are constrained by the availability of the financial resources. These resources correspond to the accumulated profits ($\Pi_{i,j,c,t}$):

$$\Pi_{i,j,c,t} = \Pi_{i,j,c,t-1} + \pi_{i,j,c,t} - I_{i,j,c,t} - R_{i,j,c,t} \tag{15}$$

3.1.3 R&D, process and product innovations

The formal representation of the R&D process is explicitly inspired by evolutionary modelling of technical change (Nelson and Winter 1982). We consider that the probability of success of research is an increasing function of R&D investments. Departing from this seminal contribution, the firms also benefit from public investments in S&T. We distinguish the impact of specific investments by the public sector in the science and technology base required specifically in the sector j, identified as *mission-oriented* projects, from investment in fundamental or more generic science and technology base.
Formally the branch of the R&D activity responsible for the development of process innovation can be represented by the following algorithm:

1. The probability of success in developing a prototype of capital good is:

$$P^a_{i,j,c,t} = 1 - e^{-\delta_a \cdot (R^{\varphi_1}_{i,j,c,t} \cdot S^{\varphi_2}_{j,c,t} \cdot S^{\varphi_3}_{c,t})}$$

   in which the firms investments in R&D $R_{i,j,c,t}$ are complemented by the public investments in S&T oriented towards the sector j ($S_{j,c,t}$), and the generic and fundamental public investments in S&T ($S_{j,c,t}$). The parameters $\varphi_1 \in [0;1]$, $\varphi_2 \in [0;1]$ and $\varphi_3 \in [0;1]$ sum to one and control the contribution of each source of knowledge, internal, external, specialized and generic to the probability of success of R&D. This formal representation implies that without own R&D investments firm cannot benefit from the public S&T investments, reflecting as well the idea of a required absorptive capacity to benefit from the latter, as well as a non-null investment in both specialized and generic knowledge from the public sector; δ_a is a parameter.

2. If R&D is successful, the embodied level of productivity ($a'_{i,j,c,t}$) for the prototype of capital good is stochastic and drawn from the following distribution:

$$a'_{i,j,c,t} \sim N(a_{i,j,c,t-1}; \sigma^a_{i,j,c}) \tag{16}$$

The prototype of capital good is then introduced into the production capacity of the firm if it allows for productivity gains hence:

$$a_{i,j,c,t} = \max\{a'_{i,j,c,t}; a_{i,j,c,t-1}\} \tag{17}$$

Following Witt (2001, 2010, 2016), the satiability of goods is a function of the characteristics of the goods, that result from firms R&D activity. In other words, product innovations allow firms to escape the satiation of their sector by expanding the range of needs or wants their products are able to satisfy.
Formally, we assume that a degree of satiability $\vartheta_{i,j,c,t}$ is embodied in each vintage of products developed and put on the market by the firms. Symmetrically to process innovation, the product improvement process also benefits from public investments in S&T:

1. The probability of success in developing a prototype of consumer good is:

$$P^{\vartheta}_{i,j,c,t} = 1 - e^{-\delta_{\vartheta} \cdot (R^{\varphi_1}_{i,j,c,t} \cdot S^{\varphi_2}_{j,c,t} \cdot S^{\varphi_3}_{c,t})}$$

in which δ_{ϑ} is a parameter.

2. If R&D is successful, the satiability embodied in the prototypes ($\vartheta'_{i,j,c,t}$) for the consumer product is stochastic and drawn from the following distribution:

$$\vartheta'_{i,j,c,t} \sim N(\vartheta_{i,j,c,t-1}; \sigma^{\vartheta}_{i,j,c}) \tag{18}$$

The prototype of good is then put into production and marketed if it allows to escape from satiation:

$$\vartheta_{i,j,c,t} = \max\{\vartheta'_{i,j,c,t}; \vartheta_{i,j,c,t-1}\} \tag{19}$$

3.2 Domestic consumption by households and income dynamics

This subsection discusses the behaviour of households, defining their consumption according to their income dynamics. The structure of the final demand is driven by the structure of households expenditures and the changes in these expenditures driven by the dynamics and distribution of income. The households in each country are divided into groups of consumers/workers. Each group constitutes a specific class of households with a homogeneous structure of expenditures as well as a homogeneous set of income. The structure of employment and income therefore defines the weight of each of the class of households.

3.2.1 Households consumption behaviour and the structure of expenditures

For the sake of simplicity, each consumer class corresponds to a specific layer of worker used in production. Hence a given consumer class h is composed of all the workers of the layer h employed in all the I firms in the J sectors.

The expenditures $C_{j,c,t}$ devoted to the goods or services provided by a given sector j formally corresponds to the sum of the expenditures devoted to the goods or services provided by this sector coming from each of the $h \in [1; H]$ consumer/worker class. All the income $W_{h,c,t}$ perceived by a class of households h is consumed. A given share $c_{h,j,c,t}$ of the income of a consumer/worker class h is devoted to the expenditure in goods or services provided by a sector j. Formally, the total expenditure devoted by households to the goods or services produced by the sector j can be given by:

$$C_{j,c,t} = \sum_{h=1}^{H} c_{h,j,c,t} \cdot W_{h,c,t} \tag{20}$$

At every time step, the expenditures shares are given for each of the households groups. In line with Kaldor (1966), the long-run distribution of expenditure shares that shapes the long-run growth pattern of economies should reflect the changes in their income structure. In this respect, we assume that the expenditures shares for each of the goods and services from the J sectors and for each of the H groups of households follow an Engel curves-like dynamics: as income raises, the expenditures by households increase up to a satiation level. Above this satiation level, for any further increase in income, the level of expenditures remains unchanged.

Following Witt (2010), the degree of satiability of each sectors is embodied in the goods themselves. The characteristics of the consumption goods define this level of satiability. Moreover, we account for the elements of the aforementioned literature on social interaction and consumption behaviour (Lorentz et al. 2016, Pasinetti 1983, Verspagen 1992), that, as income rises for a given class of consumer, their behaviour tends to imitate those of higher classes of income. Hence for each sector and each group of households, the expenditure shares $c_{h,j,c,t}$ tend to converge to the expenditure shares of the class above $c_{h+1,j,c,t}$ (Eq. (21)) while for the highest class, the shares converge to a asymptotic distribution $\bar{c}_{j,c,t}$ defined by the technological characteristics of the goods and services (see Eq. (22)):

$$c_{h,j,c,t+1} = c_{h,j,c,t} \cdot \left(1 + \eta \left(c_{h+1,j,c,t} - c_{h,j,c,t}\right) \cdot \frac{\Delta W_{h,c,t}}{W_{h,c,t-1}}\right) \; \forall h \in [1; \Lambda - 1] \tag{21}$$

$$c_{\Lambda,j,c,t+1} = c_{\Lambda,j,c,t} \cdot \left(1 + \eta \cdot \left(\bar{c}_{j,c,t} - c_{\Lambda,j,c,t}\right) \cdot \frac{\Delta W_{\Lambda,c,t}}{W_{\Lambda,c,t-1}}\right) \tag{22}$$

The parameter η controls the speed of convergence, as income rises ($\frac{\Delta W_{h,c,t}}{W_{h,c,t-1}}$). The asymptotic distribution of expenditure shares is a function of the relative satiability of each category of goods j as measured by $\vartheta_{j,c,t}$:

$$\bar{c}_{j,c,t} = \frac{\vartheta_{j,t}}{\sum_j \vartheta_{j,t}} \tag{23}$$

More formally, the level of satiation of a given category of goods j and its corresponding supplying production branch $\vartheta_{j,c,t}$ results from the aggregation of the satiability levels embodied in the products supplied by both domestic and foreign firms ($\vartheta_{i,j,c,t}$):

$$\vartheta_{j,t} = \sum_c \sum_i z_{i,j,c,t} \vartheta_{i,j,c,t} \tag{24}$$

3.2.2 Wage dynamics and income distribution

Wages constitute the sole source of income for the consumer/worker groups. On the one hand, as discussed in subsection 3.1.1, for each firm, the demand for labour of each layer of workers reflects both the level of demand addressed to the firms and the hierarchical structure of the firms. On the other hand, as discussed in subsection 3.1.1 for each firm and every layer of workers in the firm, the wages are a function of a sectoral level (minimum) wage. For a given sector j wage dynamics are correlated with the productivity growth rate ($\frac{\Delta A_{j,c,t}}{A_{j,c,t-1}}$) of the sector and with the productivity growth rates of the whole economy ($\frac{\Delta A_{c,t}}{A_{c,t-1}}$). The effect of these two variables on wage dynamics is weighted by the parameter $\gamma \in [0; 1]$. When $\gamma = 0$, the wage dynamics for every sector only depend on the productivity growth rate of the economy as a whole (i.e., as a centralised wage negotiation system). When $\gamma = 1$, the wage dynamics for every sector only depends on the productivity growth rate of the sector (i.e., as a decentralised wage negotiation system). Wage dynamics of the sector j in economy c is represented as follows:

$$\frac{\Delta w_{j,c,t}}{w_{j,c,t-1}} = \gamma \cdot \frac{\Delta A_{j,c,t}}{A_{j,c,t-1}} + (1-\gamma) \cdot \frac{\Delta A_{c,t}}{A_{c,t-1}} \tag{25}$$

The closer the parameter γ is to one, the more productivity gains are absorbed by wages. Reversely, the closer the parameter is to zero, the less the wages absorb productivity gains. This artificially increases the competitiveness of firms. In other words, the parameter γ can be interpreted as an instrument allowing to artificially amplify one's competitiveness through wage freezing.

We can the write the total number of workers in a class h, $L_{h,c,t}$, as a function of all the demand addressed to each sector $Y_{j,c,t}$:[3]

$$L_{h,c,t} = \sum_{j=1}^{J}\sum_{i=1}^{I} L_{h,i,j,c,t} = \sum_{j=1}^{J} \frac{Y_{j,c,t}}{z_{j,c,t}} \cdot \sum_{i=1}^{I} \nu^{1-h} \cdot \frac{z_{i,j,c,t}}{p_{i,j,c,t-1} \cdot A_{i,j,c,t}} \tag{26}$$

Similarly, we can express the income ($W_{h,c,t}$) of each class h of consumers/workers applying the wage grid corresponding to the h tier of workers in each firms:

$$W_{h,c,t} = \sum_{j=1}^{J}\sum_{i=1}^{I} w_{h,i,j,c,t} \cdot L_{h,i,j,c,t} \tag{27}$$

The income level of each class of households h is a function of sectoral effective demand, $Y_{j,c,t}$:

$$W_{h,c,t} = \sum_{j=1}^{J} \frac{w_{j,c,t-1}}{z_{j,c,t}} \cdot Y_{j,c,t} \cdot \sum_{i=1}^{I} \left(\frac{b}{\nu}\right)^{h-1} \cdot \frac{z_{i,j,c,t}}{p_{i,j,c,t-1} \cdot A_{i,j,c,t}} \tag{28}$$

We re-arrange the expenditures devoted by households to each sector j expressed in Eq. (20) as a function here of the level of GDP derived in a Keynesian way from the aggregation of the level effective demand of each sector j:

$$C_{j,c,t} = \underbrace{\left[\sum_{h=1}^{H} c_{h,j,c,t} \cdot \sum_{j=1}^{J} \frac{w_{j,c,t-1}}{z_{j,c,t}} \cdot s_{j,c,t} \sum_{i=1}^{I} \left(\frac{b}{\nu}\right)^{h-1} \cdot \frac{z_{i,j,c,t}}{p_{i,j,c,t-1} \cdot A_{i,j,c,t}}\right]}_{\chi_{j,t}} \cdot Y_{c,t} \tag{29}$$

Where $\chi_{j,t}$ corresponds to the Keynesian marginal propensity to consume, function of both the structure of income distribution and the structure of expenditures among households classes as well as the industrial structure of the country ($s_{j,c,t}$).[4]

3.3 International trade and market dynamics

[3]We remind that each consumer class h corresponds to a tier of workers such that $k = h$.
[4]In which $s_{j,c,t} = \frac{Y_{j,c,t}}{\sum_{j=1}^{J} Y_{j,c,t}}$.

3.3.1 Imports and Exports dynamics

Domestic consumption is either satisfied by domestic suppliers (firms i in sector j of the economy c) or by imported goods. A share $m_{j,c,t}$ of these expenditures are satisfied by imports ($M_{j,c,t}$):

$$M_{j,c,t} = m_{j,c,t} \cdot C_{j,c,t} \tag{30}$$

The share of imported goods is a function of the competitiveness of the domestic firms on the market for products of sector j. The competitiveness of domestic sector j is approximated by its market share $z_{j,c,t}$:

$$m_{j,c,t} = (1 - z_{j,c,t}) \tag{31}$$

Combining the equations above we can derive the following expression for the imports of sector j, as a function of nominal GDP of the economy:

$$M_{j,c,t} = (1 - z_{j,c,t}) \cdot \chi_{j,t} \cdot Y_{c,t} \tag{32}$$

The level of exports of an economy c for a given sector j corresponds to the share ($z_{j,c,t}$) of the imports of products from the expenditure category j from all the other countries ($\bar{c} \in [1, C] | \bar{c} \neq c$):

$$X_{j,c,t} = z_{j,c,t} \cdot \sum_{\bar{c}} M_{j,\bar{c},t} \tag{33}$$

Imports by foreign economies are constructed symmetrically to the imports of the domestic economies.[5] We can therefore rewrite the expression for the exports of sector j as follows:

$$X_{j,c,t} = z_{j,c,t} \cdot \sum_{\bar{c}} (1 - z_{j,\bar{c},t}) \cdot \chi_{j,\bar{c},t} \cdot Y_{\bar{c},t} \tag{34}$$

3.3.2 Market dynamics

International trade, as domestic markets dynamics, follows a similar pattern. The level of effective demand is shared among firms and/or economies according to their market shares. The dynamics of market shares accounts for the relative competitiveness of firms and/or economies, so that, their market share raises as long as the firms/economies competitiveness is higher than the average.

[5] Considering here an integrated economic system with a single currency, we can assume a fixed exchange rate equal to one for all economies composing the system.

More formally, the market share of the economy in a sector is a proxy for the price competitiveness of the economy in that sector and is given by the sum of the market shares of the domestic firms active therein:

$$z_{j,c,t} = \sum_i z_{i,j,c,t}$$

Each firm's market share is defined through a replicator dynamic, function of firm's relative competitiveness ($\frac{E_{i,j,c,t}}{\bar{E}_{j,t}}$):

$$z_{i,j,c,t} = z_{i,j,c,t-1} \cdot \left(1 + \varphi \cdot \left(\frac{E_{i,j,c,t}}{\bar{E}_{j,t}} - 1\right)\right)$$

where $z_{i,j,c,t}$ represents the market share of firm i, $p_{i,j,c,t}$ the price of its product. $E_{i,j,c,t}$ stands for firm i, in sector j, level of competitiveness:

$$E_{i,j,c,t} = \frac{1}{p_{i,j,c,t}}$$

and $\bar{E}_{j,t}$, the average competitiveness on the international market, is computed as follows:

$$\bar{E}_{j,t} = \sum_{c,i} z_{i,j,c,t-1} \cdot E_{i,j,c,t}$$

3.4 Aggregate demand and GDP dynamics:

As for most of the Post-Keynesian growth models, the balance-of-payment constraint has to be satisfied. The sum of all sectors exports therefore has to equal the sum of all sectors imports:

$$\sum_{j=1}^{J} X_{j,c,t} = \sum_{j=1}^{J} M_{j,c,t} \tag{35}$$

$$\sum_{j=1}^{J} z_{j,c,t} \cdot \sum_{\bar{c}} (1 - z_{j,\bar{c},t}) \cdot \chi_{j,\bar{c},t} \cdot Y_{\bar{c},t} = \sum_{j=1}^{J} (1 - z_{j,c,t}) \cdot \chi_{j,c,t} \cdot Y_{c,t} \tag{36}$$

From the balance-of-payment constraint, we derive the level of nominal GDP of the economy:

$$Y_{c,t} = \frac{1}{\left(1 - \sum_j z_{j,c,t} \cdot \chi_{j,c,t}\right)} \sum_j z_{j,c,t} \cdot \sum_{\bar{c}} (1 - z_{j,\bar{c},t}) \cdot \chi_{j,\bar{c},t} \cdot Y_{\bar{c},t} \tag{37}$$

Eq. (37) presents a typical Post-Keynesian relation: domestic GDP is a function of exports, with a typical Harrodian trade multiplier linking GDP to exports. This multiplier is a function of the structure of aggregate demand, as measured by the distribution of expenditure shares and of the competitiveness of the economy. The combination of the elements are so that the multiplier on foreign GDP, defining the level of domestic GDP as function of the structure of the economies, results from both their specialisation patterns through the exports and the structure of domestic demand.

3.5 Policy Instruments and scenarios

At each time steps the government spends a share g_c of GDP in its S&T policies to fund either mission-oriented policies or generic and fundamental research. The outcome of fundamental research is assumed to be absorbable by every sectors in the same range. Mission-oriented policies are assumed to be directed at specific sectors and its benefits can only affect the firms in the sectors that were targeted by the policy.[6] We do not explicitly model a counterpart to the public spendings (via taxes for example) as we aim at focusing on the effect of the direction of the public spendings rather than the redistributive effect due to a tax funded policy.
The policy scenarios to be considered consists in a two stage decision:

1. defining the amount of public spendings devoted to mission-oriented and to generic and fundamental S&T policies. The parameter $\psi_c \in [0;1]$ defines the share of spendings devoted to mission-oriented research in country c; $1 - \psi_c$ therefore corresponds to the share of public investment spent in generic and fundamental research and the total investment in generic research is:

$$S_{c,t} = (1 - \psi_c) \cdot g_c \cdot Y_{c,t} \tag{38}$$

2. defining the sector targeted by the public spending with mission-oriented S&T policies. Such spendings can only be allocated to one sector at the time, but can, at each time period be reallocated to a different sector, should the criterion of choice of the targeted sector identify a different industry than the previous one. We schedule three different scenarios to target the mission-oriented policies:

   (a) Pushing the technological frontier ahead: the policies are targeted to support the most advanced technology, regardless of the competitiveness of the firms from this country in the corresponding sector. Formally, the amount of public invest-

[6] For simplicity, the mission-oriented policies analysed in the experiments can be thought of as the *accelerator* type, since they concentrate and direct resources to provide technological solutions by prioritizing research activities and innovations. Furthermore, they can be distinguished from *transformers* missions which focus on broad systemic changes through the development and deployment of innovations (European Commission 2018c).

ment per sector is defined as follows:

$$S_{j,c,t} = \begin{cases} \psi_c \cdot g_c \cdot Y_{c,t} & \text{if } \vartheta_{j,t} = max\{\vartheta_{1,t}, ..., \vartheta_{J,t}\} \\ 0 & \text{otherwise} \end{cases} \tag{39}$$

(b) Creating/sustaining a position of leadership: the policies are targeted to support the most competitive sector, regardless of the product quality or the technological advancement of this sector with respect to the others. Formally, the amount of public investment per sector is defined as follows:

$$S_{j,c,t} = \begin{cases} \psi_c \cdot g_c \cdot Y_{c,t} & \text{if } z_{j,c,t} = max\{z_{1,c,t}, ..., z_{J,c,t}\} \\ 0 & \text{otherwise} \end{cases} \tag{40}$$

(c) Supporting/relaunching declining sectors: the policies are targeted to support the least competitive sector, limiting the consequences of international competition avoiding the dislocation of a declining sector of the economy c, regardless of the product quality or the technological advancement of this sector with respect to the others. Formally, the amount of public investment per sector is defined as follows:

$$S_{j,c,t} = \begin{cases} \psi_c \cdot g_c \cdot Y_{c,t} & \text{if } z_{j,c,t} = min\{z_{1,c,t}, ..., z_{J,c,t}\} \\ 0 & \text{otherwise} \end{cases} \tag{41}$$

We identify with symmetric policies the cases in which both countries adopt the same choice regarding the amount of investment in GDP and its allocation between open science and mission-oriented programs. Conversely, policies are considered as asymmetric when countries adopt different targets in mission-oriented programs.

The design of our experiments present some differences with Dosi et al. (2023), in which the focus was again on the effects of mission-oriented policies out of an entrepreneurial state. Their experiments envisaged the creation of a public capital-good firm and a National Research Lab with the aim of disseminating knowledge to private firms and to increase the probability of introducing radical innovations. That theoretical setting, though larger in its consideration of breakthrough innovations, lacks the framework to account for specialisation patterns and cross-country coordination issues.

4 Stylised facts, growth, specialisation and technical change: the baseline scenario

We perform the model with computer simulations as for most of the models incorporating evolutionary features. Tab. 1 gathers baseline parameter values. The benchmark scenario is performed along 5000 period simulations across 50 Monte Carlo runs. For simplicity, our artificial system counts two economies and four industrial sectors.[7] Each economy is producing and consuming the output of each of these sectors and counts ten active firms per sector. An economy is then composed of forty firms, and each sector counts twenty firms competing against each other. This benchmark focusses only on the private economy, no national government is involved. In addition to this, we fuel the model with an exogenous growth of external demand of 0.5%. If a single time step roughly corresponds to a quarter, exogenous demand grows of about 2% yearly. We set initial conditions such that firms start as perfectly homogeneous: the heterogeneity will emerge when the model unfolds as outcome of the interactions and different decision rules. Furthermore, initial GDP levels are the same, and all economies are equally producing in all sectors. There is no initial specialisation, since such patterns are treated as emergent outcomes of the model.[8] With this initialisation, we implicitly account for the fact that "[O]ne can hardly identify, in general, persistent features of national growth patterns just conditional on initial performances [...]. Closer inspection of particular economies or groups of them does appear to show long-term persistence [...] but the causes of the phenomenon are plausibly country-specific rather than a common feature of the world economy"(Dosi, Freeman and Fabiani 1994, p. 11). We follow Ciarli et al. (2019) in the characterisation of sectoral expenditure shares. In that work, the authors divided the economy in ten industries producing most of the goods entering the British consumption bundle. They used the UK Family Expenditure Survey (FES) 2005-2006 to compute the initial consumption shares across ten aggregate consumption categories for the top centile and the bottom decile of UK consumers. Since we are concerned with four sectors only, we took the values that refer to expenditure shares for food, motoring, leisure and power. By the way, we believe these sectors are quite general for the purpose at hand to be thought of as including most goods in the consumption bundle.

Kaldor (1960, 1961) argued that any theoretical model should be able to account for a spectrum of historical facts. As first step in our analysis, we discuss the dynamic properties of our evolutionary setting of growth and specialisation, and whether it respects some histor-

[7] The results we present below do not depend on the number of countries or sectors involved. Outcomes for a three-markets monetary union are available on request.

[8] What follows considers specialisation as the concentration of production in a limited number of sectors, namely the allocation of various activities across various economies as traditionally considered in the international trade literature.

Parameter	Description	Value
T	Time	5000
MC	Monte Carlo runs	50
i	Number of firms at country-sector level	10
j	Number of sectors at country level	4
c	Number of countries	2
φ	Market share sensitivity to competitiveness	0.09
ψ_c	Share of spending to mission-oriented policies	0
μ	Mark-up	1
ι	Share of firm's resources invested in capital goods	0.4
δ_a	Coefficient in R&D probability to innovate	0.05
δ_ϑ	Coefficient in R&D probability to innovate	0.05
γ_1	Coefficient in R&D probability to innovate	0.33
γ_2	Coefficient in R&D probability to innovate	0.33
γ_3	Coefficient in R&D probability to innovate	0.34
γ_w	Wage stickiness	0.75
g_c	Share of S&T in GDP	0
η	Convergence speed of expenditure share	0.4
ϱ	Share of firm's resources invested in R&D	0.2

Table 1. Parameter setting

ical regularities. Tab. 2 summarises the facts matched by the framework.

4.1 Growth patterns and properties of aggregate time series

Fig. 2 shows the general pattern of output, consumption, and investments. The model generates an endogenous and self-sustaining growth path characterised by tiny fluctuations (Dosi, Fabiani, Aversi and Meacci 1994, Dosi, Freeman and Fabiani 1994, Durlauf 1994).[9] Fig. 3 develops and presents Kaldor's facts (Kaldor 1960, 1961). The first fact is about the shares of national income received by labour and capital which should remain constant over long periods of time. We notice the labour share in GDP converges to a positive value in both countries after an intense span of remarkable fluctuations. Secondly, the capital-labour ratio grows over time. The endogenous growth of GDP and labour productivity (see below) coincides with a deepening in the capital intensity of the economies (Kaldor 1960, p. 260). This also means that the rates of investment in machineries are robustly correlated with economic growth (De Long, Summers and Abel 1992). Thirdly, the model engenders for both countries endogenous productivity growth rates and rates of return on investments which stabilise around positive and long-run values.[10]

The literature typically observes co-movements in most economic aggregates, e.g., GDP, investment, consumption, labour productivity (Dosi, Freeman and Fabiani 1994). Fig. 6 and Fig. 7 in Appendix plot the autocorrelation structure for de-trended labour productivity,

[9] The simulated time series follow a unit root process according to the ADF test (Tab. 14 in Appendix), well in tune with the observed evidence (Nelson and Plosser 1982). In addition to this, business-cycle fluctuations are not very clear from Monte Carlo averages, since the latter tend to wash away the variability. Sample simulations are available upon request.

[10] Kaldor underlined also the constancy of the capital-output ratio over periods: we have embedded this fact in Eq. (1).

Empirical regularity	Tab., Fig.	References
Patterns of growth and aggregate time series		
Endogenous, self-sustained growth with fluctuations	Fig. 2	Durlauf (1994), Maddison (2010)
Harrodian-Keynesian multipliers significantly above 1	Fig. 4	Deleidi, Iafrate and Levrero (2020)
Non-stationarity of macro series	Tab. 14	Hamilton (2020), Nelson and Plosser (1982)
Constant factor shares	Fig. 3	Kaldor (1960, 1961)
Growing capital-labour ratio	Fig. 3	Kaldor (1960, 1961)
Convergence to positive productivity growth rates	Fig. 3	Kaldor (1960, 1961)
Convergence to positive profit rates	Fig. 3	Kaldor (1960, 1961)
Correlation structure of key variables	Fig.s 6, 7	Assenza et al. (2015), Stock and Watson (1999)
Cyclicality of R&D	Fig.s 6, 7	Stock and Watson (1999), Wälde and Woitek (2004)
Patterns of specialisation and technical change		
Endogenous structural change	Fig. 4	Kuznets and Murphy (1966), Pasinetti (1983)
Innovation is correlated with performance on international markets	Fig. 5	Dosi, Freeman and Fabiani (1994)
Countries develop absolute technological advantages	Fig. 4	Dosi and Nelson (2010)
Exporters are larger in size than non-exporters	Fig. 5	Bernard and Jensen (1999)
Patterns of specialisation are sticky	Fig. 4	Lundvall (1992), Nelson (1993)
Productivity differences at various levels of disaggregation	Fig.s 8, 4, 5	Dosi, Freeman and Fabiani (1994)
Positive correlation between income inequality and concentration	Fig. 8, 4	Autor, Dorn, Katz, Patterson and Van Reenen (2020)

Table 2. Empirical regularities reproduced by the model

consumption, physical investment, R&D investment, output and the corresponding cross-correlation between their cyclical components and that of GDP.[11] The simulated series are quite similar to real series (Assenza, Delli Gatti and Grazzini 2015) with the first-lag auto-correlation of at least 0.8. Moreover, both types of investment are pro-cyclical and synchronised with the business cycle as in Dosi, Pereira, Roventini and Virgillito (2018) and Wälde and Woitek (2004)[12] Consumption follows with a couple of lags as in Ciarli et al. (2019) and Caiani, Godin, Caverzasi, Gallegati, Kinsella and Stiglitz (2016), while labour productivity has an unclear correlation pattern, perhaps due to the intrinsically uncertain outcome out of innovative search.

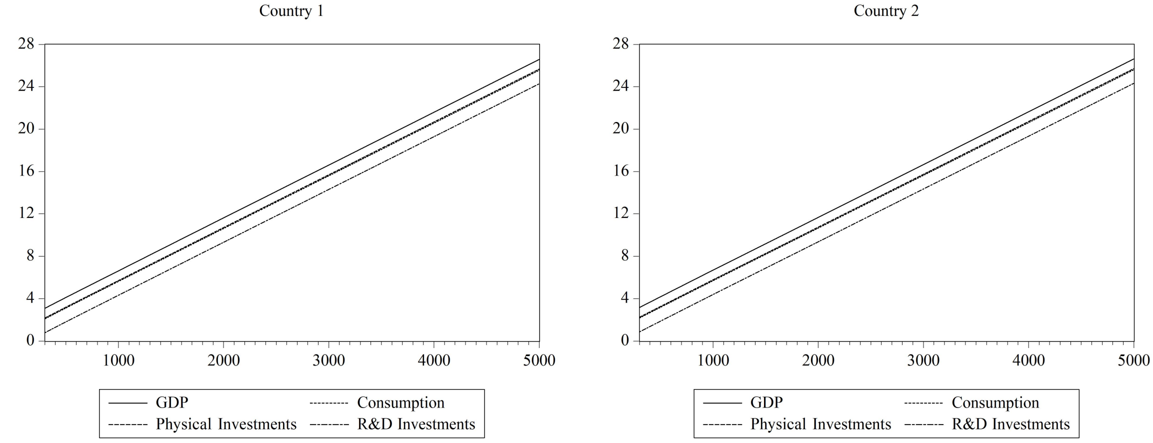
The next subsections are devoted to the description and the interpretation of specialisation and technical change patterns at union and country level.

4.2 Patterns of specialisation and technological change

Fig. 4 provides some indicators that portray development and growth dynamics at country level. The first chart is about the inverse Herfindahl index for output. This index estimates the number of sectors in which production is concentrated. Given the specification of our model, this indicator is defined in the interval $[1; 4]$. When it equals 4, the national economy produces the same level of output along the four industries: no specialisation occurs. Conversely, when it equals unity, the economy is highly specialised in a particular sector. The concentration index for both economies converges to the long-run average of 2. The second graph in Fig. 4 concerns to the coefficient of variation in labour produc-

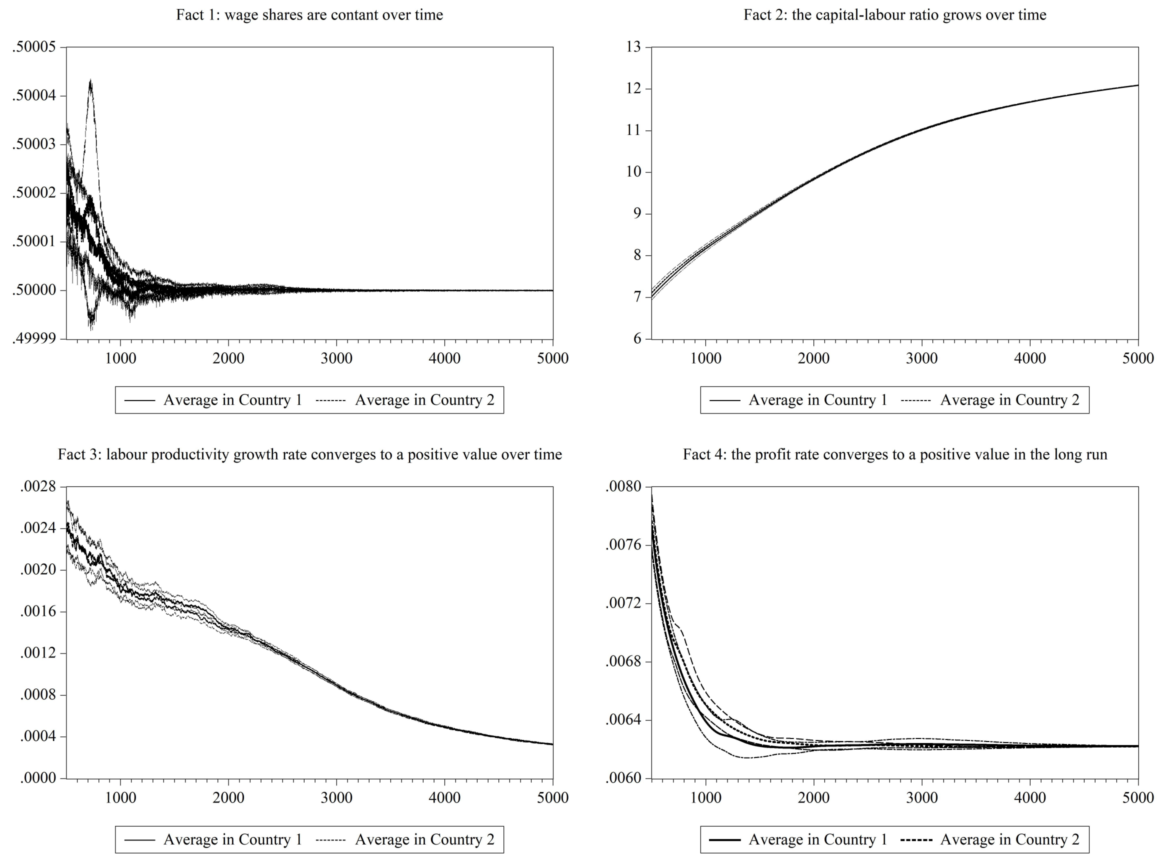
[11] We have obtained cyclical and trend components with the Hodrick-Prescott filter. Despite believed as inaccurate, performances of the HP filter were recently reconsidered in Franke, Kukacka and Sacht (2022).

[12] The cyclicality of R&D fuels an interesting debate in the literature and the empirical evidence is mixed: see also Aghion, Angeletos, Banerjee and Manova (2010), Aghion, Askenazy, Berman, Cette and Eymard (2012), Chiao (2001) and Rafferty and Funk (2004).



Note: we represent average Monte Carlo replications and we have deleted the first 300 hundreds periods to focus on the long-run stable pattern of the series.

Figure 2. Overall growth patterns



Note: we represent average Monte Carlo replications and we have deleted the first 500 hundreds periods both to focus on the long-run stable pattern of the series and to highlight the convergence mechanism. Dashed lines refer to 95% confidence intervals for Country 1, while dot-dashed lies concern to Country 2's confidence intervals. The capital-labour ratio is expressed in log terms.

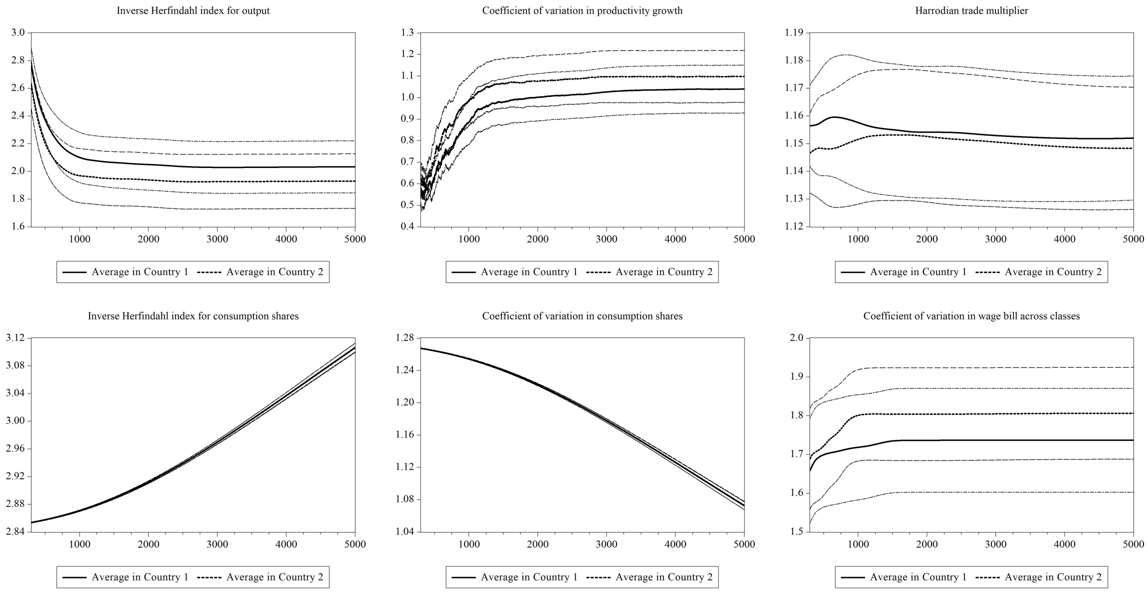
Figure 3. Kaldor's facts

tivity growth between sectors within countries. The index points to the heterogeneity of productivity dynamics across sectors. As might be expected, specialisation is driven by absolute advantages first, and the corresponding aggregate growth of income and resources afterwards implies the domestic demand for other industrial goods to grow accordingly.[13] This demand is to be satisfied and all the resources which are not absorbed by the favoured industry is distributed among the remaining ones. Hence we observe a second order specialisation process: although the remaining sectors are more and more *abandoned*, and their share in value added reduces over time, the growth rate of demand for their products is significantly positive. A non-zero growth prevents the explosion of the coefficient of variation in productivity growth and allows for its long-term stabilisation.[14]
Thirdly, Fig. 4 presents simulations of the Harrodian trade multiplier, which is significantly greater than 1 for both countries of the monetary union. Beyond constituting a rationale to supporting Keynesian policies, a stable Harrodian multiplier moves away the recent threats of Harrodian instability in agent-based models (Botte 2019, Franke 2019, Russo 2020). Last point is about income inequality: last panel in Fig. 4 reveals a coefficient of variation significantly higher than 1 for the wage bill across classes and sectors within the single country. A pattern as such envisages a positive relationship between market concentration and income inequality (Autor et al. 2020, Caiani, Russo and Gallegati 2019, Ciarli et al. 2010, 2019, Saez and Zucman 2020). As an enterprise gets all the demand for a product, it keeps on growing in terms of employment and hierarchical structure. Nevertheless, the ceiling in the number of tiers makes the difference between the amount of income which is given to the lowest tier of workers and the amount of income to the last tier increase, leading to a high variation in the level of income of each class that persists at the aggregate level too (see also the corresponding graph in Fig. 5).

Yet, the empirical growth literature remarks that the long-term patterns for the largest set of countries show an increasing differentiation in terms of GDP and productivity growth: different economies grow at different and variable rates (Durlauf, Johnson and Temple 2009a,b, Fagerberg 1987, 1994). Among the several stylised facts reproduced by our model, this setting does not exhibit divergent growth patterns. Fig. 5 shows that the coefficients of variation of GDP and labour-productivity growth between countries steadily decline to

[13] That demand for other sectoral products grows at the same rate is showed in Fig. 4, bottom panels. The inverse Herfindahl index of the consumption shares is increasing above 3, i.e., households expenditure is distributed along the several goods produced. At the same time, the coefficient of variation of expenditure shares goes to one with no tendency to approaching zero, suggesting a permanent divergence in the way households allocate their expenditure across products.

[14] The patterns of specialisation within and between countries, and its *stickiness*, i.e., favoured sectors do not change over time, also are in tune with the stream of research on the rise of specific national systems of innovation based on the peculiarities of scientific and technical infrastructures, and institutional and policy features of each country (Lundvall 1992, Nelson 1993). Moreover, productivity differences hold at several levels of statistical aggregation Dosi, Freeman and Fabiani (1994): see also Fig. 8 in Appendix.



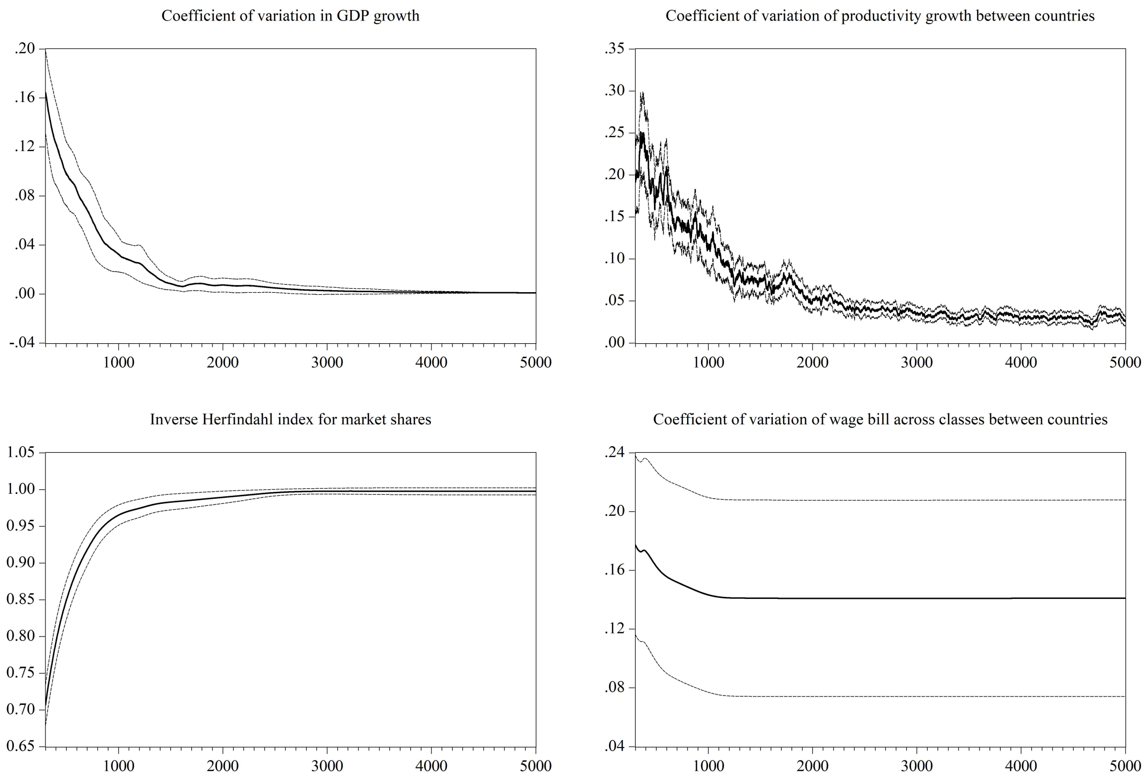
Note: we represent average Monte Carlo replications and we have deleted the first 300 hundreds periods both to focus on the long-run stable pattern of the series and to highlight the convergence mechanism. Dashed lines refer to 95% confidence intervals for Country 1, while dot-dashed lies concern to Country 2's confidence intervals. The capital-labour ratio is expressed in log terms.

Figure 4. Specialisation and technological change at country level

zero: there is growth convergence in the monetary union. We interpret this pattern reminding that economies start similar. The way they change is exactly the same, namely if one economy starts getting an advantage in terms of productivity, hence in terms of costs, this economy will have resources to spending in the quality of the product, thus changing the income elasticity for that good in that country. Yet, the range at which it changes is, on average, the same for every sector. Hence, the other economy looks like the same: another sector will experience the quality level growing, so basically the income elasticity, on average, changes the same way during the process. There is no cumulative causation mechanism in the dynamics of income elasticity and this is why we do not have divergence in the long run, but just *transitory* divergence.

In other terms, since the stochastic jumps along the innovation process follow the same random walk, when countries gain market shares through the emergence of national champions, this feature makes the increase in the resources wash away: champions do not have competitiveness anymore because they lead the respective sector.[15] The fact that there are no longer gains linked to competitiveness means that technological differences result in

[15]The structure of market at global level displays a tendency to monopoly: the inverse Herfindahl index at the bottom-left panel in Fig. 5 averages around 1, i.e., each sector is dominated by one firm. Such dynamics mirror the empirical evidence that the capabilities of innovating and adopting new technologies are positively correlated with performance in terms of export shares on international markets and income growth. The evidence suggests also that technological performance and trade performance are deeply intertwined (Bernard and Jensen 1999, Dosi, Freeman and Fabiani 1994).



Note: black lines represent Monte Carlo averages; dotted lines are 95% confidence intervals. We have deleted the first 300 hundreds periods both to focus on the long-run stable pattern of the series and to highlight the convergence mechanism.

Figure 5. Specialisation and technological change at monetary union level

transitory divergence only (Lorentz 2015a,b).

Differences in income elasticities are nonetheless not the only source of divergence in growth patterns and development trajectories. The battery of experiments in subsection 3.5 aims at testing the role of science policies in the specialisation and technical change paths. The following analysis is composed of two parts: the first is about the effects on economic growth and structural change, the second deals with the impacts upon market structure, income distribution, and consumption behaviour. For simplicity, we restrict the exposition to *symmetric* science policies, leaving the results of the *asymmetric* configuration to the Appendix.

5 Experiments: broad S&T vs. mission-oriented policies

The experiments scheduled in subsection 3.5 were organised on three criteria. The first concerns to symmetric policies where the countries joined in a monetary union apply the same science policy with respect to magnitude of research investments as share of GDP,

and of allocation of resources between mission-oriented projects and open science. In turn, mission-oriented investments target one of the following: most technologically advanced sector, most competitive sector, or the weakest industry in terms of market share.
Tab. 3 to Tab. 13 refer to the three different experiments that belong to the symmetric case. For the sake of the argument, we focus first on the dynamics around economic growth and structural change, as provided by selected indicators in Tab. 3 to Tab. 8. Secondly, we investigate the implications for the market structure, income distribution, and consumption behaviour. Results of the same type of experiments when countries choose asymmetric goals Tab. 15 to Tab. 25 are in the Appendix.

5.1 Economic growth and structural change: do symmetric policies lead to divergence?

When discussing the stylised facts matched by this setting, we have pointed out that both national economies converge to the same growth rate of GDP in the long run: Fig. 5 displayed indeed that the corresponding coefficient of variation in GDP growth was, on average, 0.3%, not statistically different from zero.
Turning our attention to the experiments and their effect on this growth dynamics, we notice the following picture in Tab. 3. Firstly, regardless of the experiment, a public sector which enters the economy through investments in research (weakly) fuels a process of economic growth divergence. Despite very few exceptions, the coefficient of variation in GDP growth departs from zero and reaches average positive values that are statistically different from the null baseline mean. This assertion holds for each pair of parameters (g_c, ψ_c). Yet, such values are still pretty small to characterise a clear divergent dynamics. In fact, economic growth in both countries is anchored to an exogenous fuel of demand that comes from the outside of the monetary union, and this component affects both economies the same.
Secondly, the relationship between the share of research investments in GDP (g_c), the allocation of such resources between mission-oriented and open science (ψ_c), and the coefficient of variation is quite non-linear. The general pattern that emerges is U-shaped: low and high pair combinations of (g_c, ψ_c) are often associated with (qualitatively) high divergent growth trajectories. Furthermore, the dynamics looks reinforced the more both countries target most resources to mission-oriented projects.
Thirdly, growth divergence is most evident when both countries focus on the most competitive sector, respectively followed by a wide support to declining sectors and to a focus on the most technologically advanced industry. Household indeed allocate their labour income according to the quality of each good: targeting a sector according to its relevance in national production might bias public investments towards goods with an inferior quality.

ψ_c , g_c	0.02	0.04	0.06	0.08	0.1
			Pushing the technological frontier ahead		
0	0.007***	0.009***	0.005***	0.114***	0.005***
0.3	0.004*	0.004*	0.020***	0.005***	0.007***
0.5	0.040***	0.005***	0.007***	0.004*	0.005***
0.7	0.005***	0.005***	0.008***	0.005***	0.006***
0.9	0.030***	0.005***	0.041***	0.006***	0.005***
1	0.007***	0.035***	0.005***	0.006***	0.005***
			Creating/sustaining a position of leadership		
0	0.007***	0.009***	0.005***	0.114***	0.005***
0.3	0.054***	0.008***	0.026***	0.011***	0.062***
0.5	0.047***	0.013***	0.018***	0.013***	0.029***
0.7	0.039***	0.025***	0.023***	0.059***	0.011***
0.9	0.036***	0.012***	0.049***	0.015***	0.034***
1	0.023***	0.045***	0.043***	0.021***	0.136***
			Sustaining/relaunching declining sectors		
0	0.007***	0.009***	0.005***	0.114***	0.005***
0.3	0.009***	0.003	0.022***	0.006***	0.062***
0.5	0.038***	0.006***	0.009***	0.003	0.035***
0.7	0.054***	0.013***	0.016***	0.045***	0.005***
0.9	0.028***	0.005***	0.049***	0.004*	0.045***
1	0.017***	0.062***	0.049***	0.004*	0.003

Note: mean values over 25 replications for the key indicator at Monetary Union level over last 4000 simulation steps. The benchmark scenario considers g_c as null. The corresponding benchmark Monte Carlo average is 0.003 with a standard deviation equal to 0.0028. The significance of the difference between the benchmark configuration and each pair of parameters is computed with a t-test: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 3. Coefficient of variation of GDP growth across experiments

The country that by chance bets on goods with a decreasing importance in the consumption bundle experiences a weaker growth performance. Conversely, and as expected, growth divergence is at minimum when both national governments try to push their technological frontier ahead, since economic growth benefits from a focus on those goods with a greater potential to be further desired by consumers.

The role of aggregate demand as engine of growth and propulsive fuel does not really change. Tab. 4 reports to the long-period Harrodian multiplier: the average value is not statistically different from the benchmark average in most cases. Anyhow, we notice a somewhat positive influence from targeting mission-oriented research to declining sectors. Being competitive and economically "alive" in a greater number if sectors reduce the denominator in Eq. (37), hence increasing the trade multiplier. Nevertheless, we circumscribe this effect to one country only and for small shares of GDP devoted to research. It is not possible to generalise such a result.

We keep on delving to divergence dynamics by gradually turning our attention to specialisation patterns. The first fact that catches the eye is in Tab. 5. Regardless of the nature of the policy experiment, science and technology policies out of the national governments are a source of divergence in productivity growth. The coefficient is now very high for each pair of parameters and is generally a positive function of the amount of public resources

ψ_c , g_c	0.02	0.04	0.06	0.08	0.1	0.02	0.04	0.06	0.08	0.1
Pushing the technological frontier ahead										
			Country 1					*Country 2*		
0	1.149	1.125**	1.118**	1.152	1.142	1.157	1.178**	1.188**	1.159	1.165
0.3	1.145	1.160	1.177	1.128*	1.136	1.155	1.142	1.129	1.175**	1.165
0.5	1.128*	1.156	1.154	1.129*	1.143	1.176**	1.147	1.151	1.174*	1.157
0.7	1.144	1.150	1.146	1.150	1.174	1.160	1.151	1.159	1.154	1.129
0.9	1.165	1.130*	1.158	1.178	1.151	1.141	1.178**	1.146	1.131	1.157
1	1.140	1.135	1.138	1.148	1.145	1.162	1.172*	1.168	1.159	1.161
Creating/sustaining a position of leadership										
			Country 1					*Country 2*		
0	1.149	1.125**	1.118**	1.152	1.142	1.157	1.178**	1.188**	1.159	1.165
0.3	1.174	1.171	1.167	1.135	1.160	1.132	1.138	1.145	1.172*	1.145
0.5	1.128*	1.151	1.158	1.137	1.156	1.179**	1.157	1.149	1.172*	1.151
0.7	1.112***	1.157	1.144	1.166	1.188**	1.200***	1.150	1.164	1.142	1.121
0.9	1.164	1.166	1.174	1.167	1.157	1.147	1.146	1.131	1.145	1.154
1	1.152	1.144	1.126*	1.165	1.146	1.156	1.163	1.188***	1.145	1.163
Sustaining/relaunching declining sectors										
			Country 1					*Country 2*		
0	1.149	1.125**	1.118**	1.152	1.142	1.157	1.178**	1.188**	1.159	1.165
0.3	1.149**	1.171	1.166	1.134	1.144	1.192***	1.138	1.147	1.174*	1.162
0.5	1.122**	1.156	1.161	1.128*	1.153	1.186***	1.153	1.147	1.182**	1.155
0.7	1.108***	1.159	1.135	1.159	1.188**	1.205***	1.147	1.175**	1.151	1.122
0.9	1.168	1.172	1.167	1.176	1.155	1.144	1.141	1.140	1.138	1.158
1	1.150	1.136	1.121**	1.169	1.175	1.159	1.173*	1.195***	1.143	1.133

Note: mean values over 25 replications for the key indicator at Country level over last 4000 simulation steps. The benchmark scenario considers g_c as null. The corresponding benchmark Monte Carlo average is 1.154 (sd = 0.071) in Country 1 and 1.147 (sd = 0.010) in Country 2. The significance of the difference between the benchmark configuration and each pair of parameters is computed with a t-test: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 4. Harrodian trade multiplier across experiments

invested in research. This is far more remarkable if compared to Fig. 5 in which the coefficient of variation averaged around a long-period position of about 5%. In other terms, the higher the share in GDP g_c, the higher the divergent productivity growth dynamics across countries. Non-linear and U-shaped is the influence of the share of a mission-oriented focus on the coefficient of variation. Basically, we have here a clear example of symmetric policies that engender divergence in productivity trajectories. This result is far more evident the more countries direct their investments from the technologically advanced sectors toward the declining ones. The more governments bring oxygen to an industry and try to sustain firms' innovative search therein, the greater the divergence between countries. Consumption behaviour and competitiveness explain this outcome. Declining sectors may either be those with a low share of expenditure in the consumption bundle because of lower quality or industries in which domestic firms have no chance to be competitive on international markets. Either way, public research investments look *wasted* towards sectors that undermine growth potentials.

Conversely, trying to push the technological frontier ahead seems crucial to dampen the divergence tendencies which are always at work with public intervention in research. In between, strengthening a position of leadership that once more underlines to the role of demand as engine of growth.

The important outcome, i.e., symmetry in research policy results in divergent trajectories of productivity growth, is paired with a corresponding shrinkage of the same divergence tendencies previously operating across sectors within countries. The focus on the private economy in the baseline setting envisaged two productivity trajectories in both countries, with productivity in a sector growing systematically twice the productivity of the other industry.[16] In this case, there are both commonalities and differences between experiments. On the one hand, a positive relationship between ψ_c and the coefficient of variation generally emerges. Even if public investments are successful in shrinking divergence tendencies across industries, the more the public agent targets a specific sector, the greater the innovation possibilities exploited inside, and then the larger the variation in productivity growth between sectors. Moreover, increases in the amount of public expenditure as share of GDP is not associated in a linear manner with corresponding hikes or reductions in the indicator of interest. On the other hand, pointing to create a position of leadership does not counteract the within-country productivity divergence. As expected, the role of public sector in this case just consists of accommodating the unfolding of the private economy already at work. In most cases, the resulting coefficient of variation turns out as not statistically different from the baseline scenario. Yet, when it is, it is also higher in value.
Additionally, we stress the importance of having a little flow of open-science investments, i.e., when ψ is strictly lower than 1. Open science is an effective means in limiting the intrinsic divergence mechanism emerging from government intervention. If there is at least a tiny flow of investments in public research whose achievements are available to all, this could still allow other industries to have innovations. If all investments are mission-oriented, i.e., when $\psi = 1$, weaker sectors do not grow and productivity differentials will worsen.

For what concerns to specialisation patterns, we claimed from Fig. 4 that both countries specialised in two different industries. The inverse Herfindahl index, which returns an indication of the number of sectors for which a country has ”active” firms, was on average equal to 1.97. Tab. 7 shows that pushing ahead the technological frontier by easing innovative search to firms which produce the good with highest quality has positive effect on the number of sectors in which a country is operative. Behind offering some preliminary insight on what could be the market structure, we find that the higher the share in GDP invested in research by the government, the higher the inverse Herfindahl index. Moreover, the share of resources devoted to mission-oriented projects is negatively associated with the same indicator. On the one hand, this means that the benefits from open science spread through the industries and eases the probability to grab fruits from innovative search at firm level. This impacts negatively upon specialisation, since an economy results more diversified in

[16] We remind that national economies specialised in two sectors each: see Fig. 4.

ψ_c , g_c	0.02	0.04	0.06	0.08	0.1
		Pushing the technological frontier ahead			
0	0.867^{***}	0.798^{***}	0.841^{***}	0.782^{***}	0.850^{***}
0.3	0.492^{***}	0.579^{***}	0.586^{***}	0.679^{***}	0.798^{***}
0.5	0.759^{***}	0.532^{***}	0.740^{***}	0.596^{***}	0.515^{***}
0.7	0.585^{***}	0.562^{***}	0.708^{***}	0.546^{***}	1.872^{***}
0.9	0.634^{***}	0.854^{***}	0.614^{***}	0.775	0.740^{***}
1	0.546^{***}	0.848^{***}	0.737^{***}	0.730^{***}	0.897^{***}
		Creating/sustaining a position of leadership			
0	0.867^{***}	0.798^{***}	0.841^{***}	0.782^{***}	0.850^{***}
0.3	0.821^{***}	0.790^{***}	0.159^{***}	0.944^{***}	0.828^{***}
0.5	0.811^{***}	0.815^{***}	0.910^{***}	0.885^{***}	0.859^{***}
0.7	1.090^{***}	0.807^{***}	0.847^{***}	0.785^{***}	0.852^{***}
0.9	0.797^{***}	0.858^{***}	0.817^{***}	0.823^{***}	0.890^{***}
1	0.896^{***}	1.675^{***}	0.848^{***}	0.760^{***}	0.775^{***}
		Sustaining/relaunching declining sectors			
0	0.867^{***}	0.798^{***}	0.841^{***}	0.782^{***}	0.850^{***}
0.3	0.990^{***}	1.000^{***}	1.710^{***}	1.000^{***}	1.002^{***}
0.5	0.990^{***}	1.043^{***}	0.998^{***}	1.015^{***}	1.011^{***}
0.7	1.365^{***}	1.068^{***}	0.992^{***}	1.035^{***}	1.001^{***}
0.9	1.069^{***}	0.997^{***}	1.059^{***}	0.998^{***}	1.020^{***}
1	0.995^{***}	2.274^{***}	1.095^{***}	0.998^{***}	1.000^{***}

Note: mean values over 25 replications for the key indicator at Monetary Union level over last 4000 simulation steps. The benchmark scenario considers g_c as null. The corresponding benchmark Monte Carlo average is 0.047 with a standard deviation equal to 0.008. The significance of the difference between the benchmark configuration and each pair of parameters is computed with a t-test: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 5. Coefficient of variation of productivity growth between countries across experiments

ψ_c , g_c	0.02	0.04	0.06	0.08	0.1	0.02	0.04	0.06	0.08	0.1
					Pushing the technological frontier ahead					
			Country 1					*Country 2*		
0	0.934^{*}	1.117	1.158	0.940	0.830^{***}	0.789^{***}	0.545^{***}	0.614^{***}	0.898^{**}	0.892^{**}
0.3	0.578^{***}	0.618^{***}	0.460^{***}	0.774^{***}	0.802^{***}	0.599^{***}	0.701^{***}	0.777^{***}	0.468^{***}	0.789^{***}
0.5	1.072	0.730	0.775^{***}	0.708^{***}	0.560^{***}	0.847^{***}	0.641^{***}	0.650^{***}	0.450^{***}	0.670^{***}
0.7	0.589^{***}	0.899^{**}	0.819^{***}	0.845^{***}	0.322^{***}	0.523^{***}	0.634^{***}	0.648^{***}	0.732^{***}	0.858^{***}
0.9	0.578^{***}	1.068	0.709	0.572^{***}	0.736^{***}	0.888^{**}	0.662^{***}	0.771^{***}	0.883^{***}	0.721^{***}
1	0.758^{***}	1.231^{**}	0.865^{***}	0.932^{*}	0.918^{*}	0.588^{***}	0.608^{***}	0.703^{***}	0.867^{**}	0.856^{***}
					Creating/sustaining a position of leadership					
			Country 1					*Country 2*		
0	0.934^{*}	1.117	1.158	0.940	0.830^{***}	0.789^{***}	0.545^{***}	0.614^{***}	0.898^{**}	0.892^{**}
0.3	0.966	1.123	0.980	1.099	0.996	1.257^{***}	1.141	1.177^{*}	0.887^{**}	1.211^{**}
0.5	1.320^{***}	1.140	1.065	1.148	1.119	1.025	1.076	0.954	1.009	1.150
0.7	1.303^{***}	1.326^{***}	1.265^{***}	1.205^{*}	0.816	0.927^{*}	1.085	0.957	1.228^{**}	1.183^{*}
0.9	1.015	1.059	1.079	1.036	1.072	1.271^{***}	1.123	1.281^{***}	1.189^{*}	1.189^{*}
1	0.967	1.349^{***}	1.338^{***}	1.103	1.335^{***}	1.232^{**}	0.899^{**}	1.002	1.259^{***}	1.103
					Sustaining/relaunching declining sectors					
			Country 1					*Country 2*		
0	0.934^{*}	1.117	1.158	0.940	0.830^{***}	0.789^{***}	0.545^{***}	0.614^{***}	0.898^{**}	0.892^{**}
0.3	1.038	0.829^{***}	0.806^{***}	1.016	0.925^{*}	0.761^{***}	0.880^{**}	1.036	0.669^{***}	0.897^{**}
0.5	1.175	0.963	0.982^{***}	1.009	1.008	0.758^{***}	0.896^{**}	0.873^{**}	0.827^{***}	0.897^{**}
0.7	1.238^{***}	1.114	1.141	1.074	0.548^{***}	0.760^{***}	0.900^{**}	0.823^{***}	1.034	1.236^{**}
0.9	0.760^{***}	0.810^{***}	0.988	0.752^{***}	0.881^{**}	1.172	1.031	1.033	1.016	1.022
1	0.790^{***}	1.310^{***}	1.230^{**}	0.889^{**}	0.759^{***}	1.034	0.614^{***}	0.828^{***}	1.096	0.970

Note: mean values over 25 replications for the key indicator at Country level over last 4000 simulation steps. The benchmark scenario considers g_c as null. The corresponding benchmark Monte Carlo average is 1.061 (sd = 0.371) in Country 1 and 1.054 (sd = 0.367) in Country 2. The significance of the difference between the benchmark configuration and each pair of parameters is computed with a t-test: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 6. Coefficient of variation of productivity growth within countries across experiments

ψ_c , g_c	0.02	0.04	0.06	0.08	0.1	0.02	0.04	0.06	0.08	0.1
					Pushing the technological frontier ahead					
			Country 1					*Country 2*		
0	2.337***	1.923	1.914	2.213*	2.383***	2.547***	2.974***	2.795***	2.491***	2.496***
0.3	2.993***	2.749***	3.041***	2.504***	2.426***	3.153***	2.732***	2.594***	2.969***	2.705***
0.5	2.217*	2.743***	2.601***	2.594***	2.815***	2.568***	2.655***	2.603***	3.031***	2.847***
0.7	2.794***	2.678***	2.475***	2.524***	3.209***	2.905***	2.739***	2.753***	2.777***	2.530***
0.9	2.836***	2.166	2.678***	2.666***	2.559***	2.383***	2.573***	2.808***	2.306***	2.476***
1	2.652***	1.834	2.296**	2.318***	2.266**	3.013***	2.721***	2.703***	2.532***	2.485***
					Creating/sustaining a position of leadership					
			Country 1					*Country 2*		
0	2.337***	1.923	1.914	2.213*	2.383***	2.547***	2.974***	2.795***	2.491***	2.496***
0.3	2.466***	2.041	2.284**	1.870	2.228**	1.982	2.030	1.990	2.353***	2.115
0.5	1.951	2.038	2.117	1.931	2.101	2.315***	2.080	2.312***	2.111	2.159
0.7	1.807	2.160	1.848	2.059	2.432***	2.468***	2.094	2.304***	2.102	1.656***
0.9	2.198*	2.194*	2.200*	2.111	2.120	1.859	1.986	2.130	2.003	2.017
1	2.308***	1.708**	1.710**	2.058	2.063	2.281**	2.439***	2.312***	1.980	2.102
					Sustaining/relaunching declining sectors					
			Country 1					*Country 2*		
0	2.337***	1.923	1.914	2.213*	2.383***	2.547***	2.974***	2.795***	2.491***	2.496***
0.3	1.987	2.150	2.304***	1.908	2.145	2.397***	2.108	2.047	2.410***	2.333***
0.5	1.978	2.183*	2.204*	1.875	2.166	2.441***	2.062	2.313***	2.284**	2.250**
0.7	1.788	2.289**	1.794	2.078	2.473***	2.590***	2.122	2.499***	2.280**	1.740*
0.9	2.320***	2.326***	2.167	2.284**	2.132	1.883	1.963	2.369***	1.949	2.144
1	2.358***	1.722**	1.678**	2.115	2.282**	2.344***	2.581***	2.472***	2.064	2.101

Note: mean values over 25 replications for the key indicator at Country level over last 4000 simulation steps. The benchmark scenario considers g_c as null. The corresponding benchmark Monte Carlo average is 1.973 (sd = 0.627) in Country 1 and 1.978 (sd = 0.626) in Country 2. The significance of the difference between the benchmark configuration and each pair of parameters is computed with a t-test: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 7. Inverse Herfindahl index of output across experiments

its portfolio of productions. On the other hand, this process is slightly counterbalanced when the importance of mission-oriented research gains in relevance. Though always significantly higher than the baseline average, the index reduces for greater ψ_c: specialisation patterns then strengthen.
By contrast, the impact of targeting leader sectors or the weakest ones is not straightforward. Most of the times, the indicator is not statistically significant from the baseline. Yet, when it is, it is greater than the baseline average, suggesting the positive influence on the structure of production out of public investments in open science.

To conclude this subsection on economic growth and specialisation patterns, Tab. 8 is about the average capital-labour ratio at country level. This indicator bridges what we discussed so far with the next analysis. It is important to note that the capital-labour ratio halves from the average benchmark in all experiments and for each pair of parameters. Additionally, the negative relationship that in general seems to hold between public investments in science and the level of the capital-labour ratio is attenuated when mission-oriented investments sustain a position of leadership, i.e., the sector with the highest share in country's production. The reason behind this outcome may lie in the several market structures. To anticipate what follows, public investments increase the degree of competition within markets. On the one hand, many more firms are able to make profits. On the other hand, the magnitude of profits per-firm is lower. This feature results in lower firm ca-

ψ_c , g_c	0.02	0.04	0.06	0.08	0.1	0.02	0.04	0.06	0.08	0.1
					Pushing the technological frontier ahead					
			Country 1					*Country 2*		
0	5.418***	5.495***	5.443***	8.133***	5.457***	5.379***	5.329***	5.331***	5.473***	5.455***
0.3	5.331***	5.393***	5.228***	5.260***	5.429***	5.245***	5.507***	5.317***	5.220***	5.282***
0.5	5.485***	5.292***	5.314***	5.381***	5.394***	5.695***	5.351***	5.332***	5.202***	5.349***
0.7	5.280***	5.388***	5.362***	5.379***	5.225***	5.227***	5.349***	5.271***	5.317***	5.371***
0.9	5.438***	5.396***	5.348***	5.340***	5.279***	5.394***	5.310***	5.559***	5.361***	5.313***
1	5.357***	5.534***	5.378***	5.447***	5.446***	5.252***	2.745***	5.361***	5.407***	5.423***
					Creating/sustaining a position of leadership					
			Country 1					*Country 2*		
0	5.418***	5.495***	5.443***	8.133***	5.457***	5.379***	5.329***	5.331***	5.473***	5.455***
0.3	8.691***	9.479***	8.709***	7.792***	8.782***	9.240***	9.323***	8.907***	7.274***	8.953***
0.5	9.055***	9.133***	8.406***	8.732***	9.121***	9.063***	8.493***	8.458***	9.311***	8.914***
0.7	8.525***	8.953***	8.571***	8.946***	8.657***	8.804***	8.689***	9.079***	9.458***	8.917***
0.9	9.219***	8.898***	8.898***	9.123***	8.689***	9.163***	8.669***	9.138***	8.908***	8.886***
1	7.949***	9.254***	8.933***	9.419***	9.130***	8.156***	9.217***	9.134***	9.445***	9.759***
					Sustaining/relaunching declining sectors					
			Country 1					*Country 2*		
0	5.418***	5.495***	5.443***	8.133***	5.457***	5.379***	5.329***	5.331***	5.473***	5.455***
0.3	5.371***	5.451***	5.305***	5.337***	5.433***	5.210***	5.482***	5.363***	5.176***	6.856***
0.5	5.467***	5.322***	5.247***	5.528***	5.461***	5.568***	5.356***	5.284***	5.234***	5.571***
0.7	6.197***	5.347***	5.443***	5.784***	5.287***	5.166***	5.382***	5.256***	5.362***	5.428***
0.9	5.416***	5.258***	5.341***	5.348***	5.872***	5.503***	5.418***	6.012***	5.402***	5.317***
1	5.320***	5.507***	6.233***	5.433***	5.395***	5.284***	6.851***	5.255***	5.461***	5.488***

Note: mean values over 25 replications for the key indicator at Country level over last 4000 simulation steps. The benchmark scenario considers g_c as null. The corresponding benchmark Monte Carlo log-average is 11.193 (sd = 0.030) in Country 1 and 11.186 (sd = 0.028) in Country 2. The significance of the difference between the benchmark configuration and each pair of parameters is computed with a t-test: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 8. Capital-labour ratio across experiments

pabilities both to hire scientists to carry out R&D at firm level and to exploit the innovation fruits through investments in capital stock. Profits constrain innovation possibilities when spread across a higher number of firms.

5.2 Market structure, income distribution, and consumption behaviour

To follow on the discussion begun previously, we present in Tab. 9 to Tab. 13 the evolution of market structure, income distribution and consumption shares with reference to the usual policy experiments.

Tab. 9 is about the inverse Herfindahl index for the market shares. This indicator, averaged between countries, gives some insight on what is the prevailing structure in the several markets. The baseline average, where we did not consider any role for national governments, was very high and close to 1 (Fig. 4). Moreover, a standard deviation of about 0.4% did not leave room for large differences across sectors, countries, and simulations. In short, markets were dominated by the respective, winner-takes-all monopolist. Once we introduce governments and public policies, the overall picture changes in a considerable way. Monopoly is no longer at work. In every market, on average, there is a strong competition that can at most be proxied by oligopoly. The Herfindahl index always ranges between 0.25 and 0.5. Since in every market there are ten equal firms at the beginning of each simulation, a maximum value of roughly 0.5 means that the less competitive setting is a duopoly.

ψ_c , g_c	0.02	0.04	0.06	0.08	0.1
	Pushing the technological frontier ahead				
0	0.363***	0.387***	0.391***	0.220***	0.334***
0.3	0.258***	0.334***	0.263***	0.258***	0.320***
0.5	0.424***	0.292***	0.305***	0.271***	0.308***
0.7	0.257***	0.350***	0.324***	0.334***	0.282***
0.9	0.312***	0.342***	0.321***	0.311***	0.307***
1	0.291***	0.435***	0.342***	0.379***	0.322***
	Creating/sustaining a position of leadership				
0	0.363***	0.387***	0.391***	0.220***	0.334***
0.3	0.467***	0.603***	0.479***	0.420***	0.513***
0.5	0.526***	0.491***	0.426***	0.478***	0.522***
0.7	0.460***	0.528***	0.503***	0.521***	0.528***
0.9	0.524***	0.490***	0.533***	0.545***	0.517***
1	0.458***	0.553***	0.521***	0.573***	0.555***
	Sustaining/relaunching declining sectors				
0	0.363***	0.387***	0.391***	0.220***	0.334***
0.3	0.269***	0.263***	0.281***	0.270***	0.272***
0.5	0.282***	0.290***	0.283***	0.292***	0.294***
0.7	0.296***	0.306***	0.303***	0.305***	0.279***
0.9	0.292***	0.298***	0.310***	0.281***	0.294***
1	0.263***	0.319***	0.326***	0.314***	0.256***

Note: mean values over 25 replications for the key indicator at Monetary Union level over last 4000 simulation steps. The benchmark scenario considers g_c as null. The corresponding benchmark Monte Carlo average is 0.998 with a standard deviation equal to 0.004. The significance of the difference between the benchmark configuration and each pair of parameters is computed with a t-test: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 9. Inverse Herfindahl index of market shares across experiments

Moreover, when comparing the results out of each experiment, we find that creating and supporting a position of leadership accommodate the concentration tendencies which were in place in the benchmark configuration. Conversely, supporting the technological frontier and declining sectors both report on average to a market concentration lower than for the aforementioned experiment. As above, this overall competitive market structure can be at the base of the lower levels of the capital-labour ratio. Smaller active firms, while probably raising the innovation rate measured as number of innovation draws per active firm, suffer from a reduced amount of per-capita profits to be re-invested. This results both in fewer innovation fruits and in a lower exploitation of productivity gains by physical investments as in Eq. (12).

The competitive setting, regardless of the experiments, is associated with a decrease of income inequality at country level, measured by the coefficient of variation of the wage bill earned across income classes. In Fig. 4 we highlighted the mechanism behind the positive link between concentration and inequality. The winner-takes-all dynamics entailed a rise in the hierarchical complexity at firm level: the ceiling in the number of employment tiers allowed for a sustained accumulation of income in the top tier, which, when compared to the income earned at the bottom tier, led to high income inequality. Public policies reverse this tendency: a competitive market structure implies an agile hierarchical structure, namely smaller firms, hence the deviation between what earned by top and bottom tiers of the em-

ψ_c , g_c	0.02	0.04	0.06	0.08	0.1	0.02	0.04	0.06	0.08	0.1
					Pushing the technological frontier ahead					
			Country 1					*Country 2*		
0	1.672*	1.746	1.633**	1.613**	1.651**	1.608*	1.550**	1.480***	1.547**	1.433***
0.3	1.510***	1.528***	1.448***	1.577***	1.553***	1.450***	1.520***	1.602**	1.406***	1.469***
0.5	1.670*	1.576***	1.537***	1.537***	1.502***	1.652	1.533***	1.513***	1.477***	1.582**
0.7	1.516***	1.626**	1.632**	1.539***	1.417***	1.439***	1.535***	1.538***	1.477***	1.607*
0.9	1.518***	1.711	1.503***	1.573***	1.592***	1.540***	1.515***	1.473***	1.561**	1.515***
1	1.615**	1.757	1.631**	1.612**	1.645**	1.496***	1.629*	1.521***	1.515***	1.455***
					Creating/sustaining a position of leadership					
			Country 1					*Country 2*		
0	1.672*	1.746	1.633**	1.613**	1.651**	1.608*	1.550**	1.480***	1.547**	1.433***
0.3	1.623**	1.716	1.551***	1.753	1.618**	1.626*	1.602**	1.773	1.570**	1.575**
0.5	1.676*	1.637**	1.663*	1.712	1.593***	1.697	1.556**	1.517***	1.537***	1.700
0.7	1.729	1.712	1.805	1.517***	1.595***	1.558**	1.602**	1.555**	1.712	1.735
0.9	1.599***	1.619**	1.659*	1.626**	1.670*	1.656	1.722	1.664	1.686	1.655
1	1.552***	1.760	1.804	1.103***	1.730	1.696	1.632*	1.669	1.259***	1.546***
					Sustaining/relaunching declining sectors					
			Country 1					*Country 2*		
0	1.672*	1.746	1.633**	1.613**	1.651**	1.608*	1.550**	1.480***	1.547**	1.433***
0.3	1.585***	1.591***	1.490***	1.715	1.625**	1.515***	1.502**	1.673	1.521***	1.486***
0.5	1.687	1.595***	1.599***	1.678*	1.555***	1.557***	1.498***	1.495***	1.474***	1.622*
0.7	1.688	1.654**	1.755	1.456***	1.528***	1.482***	1.570**	1.526***	1.591**	1.727
0.9	1.476***	1.556***	1.615**	1.548***	1.560***	1.632	1.699	1.571**	1.621*	1.574***
1	1.527***	1.778	1.740	1.580***	1.604***	1.624*	1.493***	1.552**	1.613*	1.552**

Note: mean values over 25 replications for the key indicator at Country level over last 4000 simulation steps. The benchmark scenario considers g_c as null. The corresponding benchmark Monte Carlo average is 1.822 (sd = 0.416) in Country 1 and 1.779 (sd = 0.449) in Country 2. The significance of the difference between the benchmark configuration and each pair of parameters is computed with a t-test: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 10. Coefficient of variation of wage bill within countries across experiments

ployment distribution is reduced. This mechanism shrinks income inequality. Nonetheless, income inequality is fostered by increases in the share of mission-oriented investments and by a policy that supports a position of leadership. Both are indeed positively correlated with a concentration of the market, even if the average value of the indicator is still significantly lower that the baseline's.

At monetary-union level, the two countries look a little more unequal in the way they distribute income on their inside. The average coefficient of variation around 10% in the baseline suggesting that economies shared almost the same degree of income inequality. Even if we do not witness huge changes after the diverse experiments, it seems that national economies start following different trajectories in the way income is allocated across classes. On average the coefficient of variation of the wage bill across classes and countries is around 25%. This heterogeneity in inequality between countries can be explained either by differences in firms size or sectoral productivity differences. However, experiments overall suggested a reduction in productivity differentials across sectors. This means that science policies lead to a competitive setting in which surviving firms are larger in size, counterbalancing the overall reduction of income inequality within countries. This outcome was not at work in the benchmark because the sectors in which a given country did not specialise had very small firms with barely no productivity, and also wage, differentials. This feature contributed to dampen cross-country inequality.

ψ_c , g_c	0.02	0.04	0.06	0.08	0.1
			Pushing the technological frontier ahead		
0	0.198**	0.195**	0.199**	0.384***	0.220**
0.3	0.112	0.182*	0.145	0.189*	0.200**
0.5	0.172	0.161	0.207**	0.180	0.145
0.7	0.148	0.138	0.177	0.186*	0.146
0.9	0.196**	0.236**	0.176	0.207**	0.193*
1	0.149	0.195**	0.200**	0.226***	0.260***
			Creating/sustaining a position of leadership		
0	0.198**	0.195**	0.199**	0.384***	0.220**
0.3	0.247***	0.235***	0.211**	0.254***	0.257***
0.5	0.229***	0.265***	0.228***	0.229***	0.217**
0.7	0.215**	0.247 ***	0.257***	0.242***	0.269***
0.9	0.239***	0.240***	0.210***	0.242***	0.226***
1	0.221***	0.238***	0.216***	0.273***	0.236***
			Sustaining/relaunching declining sectors		
0	0.198**	0.195**	0.199**	0.384***	0.220**
0.3	0.265***	0.275***	0.266***	0.282***	0.260***
0.5	0.276***	0.267***	0.252***	0.272***	0.276***
0.7	0.266***	0.260***	0.289***	0.271***	0.284***
0.9	0.294***	0.269***	0.261***	0.280***	0.271***
1	0.250***	0.279***	0.283***	0.298***	0.274***

Note: mean values over 25 replications for the key indicator at Monetary Union level over last 4000 simulation steps. The benchmark scenario considers g_c as null. The corresponding benchmark Monte Carlo average is 0.108 with a standard deviation equal to 0.218. The significance of the difference between the benchmark configuration and each pair of parameters is computed with a t-test: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 11. Coefficient of variation of wage bill between countries across experiments

Finally, Tab. 12 and Tab. 13 analyse how households allocate their consumption. No evident or remarkable outcome does emerge. In most cases, with few quantitative but not qualitatively exceptions, results are not statistically different from the baseline. Fig. 4 showed that consumers distributed their income along all the several goods in the market, while the relevance of each good in the consumption bundle displayed no convergence, i.e., goods with higher quality were always preferred. This statement is still valid after the experiments. Science policies by the governments do not significantly affect households preferences. As we are going to state below, this outcome raises concerns about the sufficiency of supply-side science policies in facing grand societal challenges. As argued by Foray et al. (2012, p. 1701), among the many others: "[I]t is important that public R&D programs maintain good communications with users of technologies that the programs seek to help develop or improve, and that program managers have a good understanding of user needs", with the corresponding recommendation of demand-side policies besides the supply-side's.

Next Section offers some implications for policy, sketches the future research questions and concludes the article.

ψ_c , g_c	0.02	0.04	0.06	0.08	0.1	0.02	0.04	0.06	0.08	0.1
					Pushing the technological frontier ahead					
			Country 1					*Country 2*		
0	2.980	2.979	2.979	2.972***	2.982	2.981	2.984**	2.985***	2.972	2.983*
0.3	2.981	2.982	2.983*	2.980	2.981	2.982	2.982	2.977	2.984**	2.983*
0.5	2.980	2.981	2.981	2.981	2.981	2.980	2.981	2.981	2.984**	2.981
0.7	2.981	2.981	2.981	2.982	2.984**	2.982	2.981	2.982	2.983*	2.979
0.9	2.979	2.980	2.982	2.982	2.980	2.980	2.983*	2.979	2.979	2.980
1	2.980	2.979	2.981	2.981	2.981	2.982	2.980	2.984**	2.982	2.982
					Creating/sustaining a position of leadership					
			Country 1					*Country 2*		
0	2.980	2.979	2.979	2.972***	2.982	2.981	2.984**	2.985***	2.972	2.983*
0.3	2.984**	2.984**	2.983*	2.981	2.987***	2.980	2.983*	2.979	2.984**	2.983*
0.5	2.984**	2.977	2.117***	2.978	2.981	2.984**	2.974**	2.312***	2.981	2.971***
0.7	2.966**	2.982	2.981	2.973***	2.986**	2.980	2.980	2.983*	2.977	2.980
0.9	2.974**	2.983*	2.984**	2.981	2.974**	2.975*	2.981	2.977	2.979	2.975*
1	2.979	2.980	2.968***	2.988***	2.977	2.980	2.979	2.981	2.988***	2.983*
					Sustaining/relaunching declining sectors					
			Country 1					*Country 2*		
0	2.980	2.979	2.979	2.972***	2.982	2.981	2.984**	2.985***	2.972	2.983*
0.3	2.979	2.982	2.982	2.980	2.981	2.983*	2.981	2.977	2.983*	2.977
0.5	2.979	2.982	2.981	2.980	2.980	2.980	2.981	2.981	2.983*	2.977
0.7	2.973	2.981	2.976	2.977	2.984**	2.984**	2.979	2.983*	2.981	2.979
0.9	2.979***	2.983*	2.981	2.982	2.972***	2.979	2.980	2.977	2.979	2.976
1	2.977	2.978	2.973***	2.981	2.983*	2.979	2.979	2.984**	2.980	2.981

Note: mean values over 25 replications for the key indicator at Country level over last 4000 simulation steps. The benchmark scenario considers g_c as null. The corresponding benchmark Monte Carlo average is 2.979 (sd = 0.010) in both Countries. The significance of the difference between the benchmark configuration and each pair of parameters is computed with a t-test: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 12. Inverse Herfindahl index for consumption shares across experiments

ψ_c , g_c	0.02	0.04	0.06	0.08	0.1	0.02	0.04	0.06	0.08	0.1
					Pushing the technological frontier ahead					
			Country 1					*Country 2*		
0	1.170	1.171	1.171	1.176***	1.169	1.169	1.166***	1.166***	1.171	1.168*
0.3	1.169	1.168*	1.168*	1.170	1.169	1.169	1.169	1.173	1.167**	1.167**
0.5	1.170	1.169	1.170	1.170	1.170	1.170	1.170	1.170	1.167**	1.169
0.7	1.170	1.169	1.170	1.169	1.167	1.169	1.169	1.168*	1.168*	1.171
0.9	1.171	1.170	1.169	1.168*	1.170	1.170	1.168*	1.171	1.171	1.170
1	1.170	1.171	1.169	1.170	1.170	1.169	1.170	1.167**	1.168*	1.168*
					Creating/sustaining a position of leadership					
			Country 1					*Country 2*		
0	1.170	1.171	1.171	1.176***	1.169	1.169	1.166***	1.166***	1.171	1.168*
0.3	1.167**	1.167**	1.167**	1.170	1.164***	1.170	1.167**	1.171	1.167**	1.168*
0.5	1.167**	1.173	1.171	1.172	1.170	1.167**	1.174*	1.171	1.170	1.177***
0.7	1.181***	1.168*	1.169	1.175**	1.166***	1.170	1.170	1.169	1.172	1.170
0.9	1.175**	1.168*	1.167**	1.169	1.175**	1.174*	1.169	1.172	1.171	1.174*
1	1.171	1.170	1.179***	1.164***	1.172	1.170	1.171	1.169	1.164***	1.168*
					Sustaining/relaunching declining sectors					
			Country 1					*Country 2*		
0	1.170	1.171	1.171	1.176***	1.169	1.169	1.166***	1.166***	1.171	1.168*
0.3	1.585***	1.591***	1.490***	1.715	1.625**	1.515***	1.502**	1.673	1.521***	1.486***
0.5	1.687	1.595***	1.599***	1.678*	1.555***	1.557***	1.498***	1.495***	1.474***	1.622*
0.7	1.688	1.654**	1.755	1.456***	1.528***	1.482***	1.570**	1.526***	1.591**	1.727
0.9	1.476***	1.556***	1.615**	1.548***	1.560***	1.632	1.699	1.571**	1.621*	1.574***
1	1.172	1.172	1.175**	1.169	1.168*	1.171	1.171	1.167**	1.170	1.169

Note: mean values over 25 replications for the key indicator at Country level over last 4000 simulation steps. The benchmark scenario considers g_c as null. The corresponding benchmark Monte Carlo average is 1.171 (sd = 0.007) in both Countries. The significance of the difference between the benchmark configuration and each pair of parameters is computed with a t-test: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 13. Coefficient of variation of consumption shares across experiments

6 Conclusions and policy implications

The main purpose of this paper was to analyse the outcomes in terms of economic growth, structural and technological change as result of governments' investments in science. We were particularly interested in the emergence of trade-off, if any and which ones, and macroeconomic impacts on countries integrated in a Monetary Union. The role of the public sector was, for simplicity, restricted to the allocation of a share of GDP between open science and mission-oriented programs. Several relevant results with key policy implications emerge from our numerical simulations.

Firstly, we remark the role of national governments as source of growth divergence. We have started our analysis by focussing on the private side of the economy only. In that baseline, countries used to specialise in the pair of sectors in which they were most competitive. Their growth path was anchored to the exogenous growth rate of world demand and both economies experienced convergence in GDP and productivity growth at aggregate level. By contrast, persistent productivity differentials held across sectors. Introducing government intervention by means of investments in science and technology policy along different shares of GDP, and the allocation of these resources between open science and mission-oriented research, have triggered growth divergence mechanisms. On the one hand, the pattern of divergence in GDP growth is weak but statistically different from the baseline configuration, whose average measure of divergence fades after a transitory period. On the other hand, public policies, even when symmetric in terms of share of GDP invested and resources allocation, fuel a strong and persistent divergence in labour productivity growth. Such a divergence is far more evident when countries do not target those sectors at the domestic technological frontier. Since households prefer consuming high-quality goods, investing in the domestic most, or least, competitive industries might result in strengthening the national position in the production of goods which are gradually less important in the consumption basket. The dynamic increasing returns to scale that link demand growth with productivity gains would then diminish and trigger divergence in growth paths.

The related policy implication is a call for coordination at a supranational level. Even if countries adopt symmetric policies, this is not sufficient to escape from divergence trajectories. A supranational institution such as the European Commission could schedule compensating mechanisms and incentives to strengthen technological transfers and collaborations across countries. We should remember in this case all the benefits in terms of productivity or innovation rates, however measured, from networks and spillovers: they are particularly important when the technological trajectories are highly indeterminate, i.e., when the range of development paths is large and the value of direct interactions increases (Salter and Martin 2001). In other words, coordinated policies at supranational level can be useful not only to stop averse divergence dynamics or low-growth traps, but they can be crucial also for leading countries strongly engaged in mission-oriented programs which, by definition, cope with the emergence of new technologies. Furthermore and always with reference to the European Union, the technological diversity in terms of competences and learning processes across EU members should be a stimulus to devising *cohesion* policies *à la* Cohendet and Llerena (1997) in which the several European local systems of innovation interact and learn, "defining viable solutions for collective sharing of the mode of appropriation of new technologies, organizing the mechanisms of normalization and standardization, anticipating the need of gateways technologies when lock-in mechanisms lead to a non-competitive array of technological solutions" (Cohendet and Llerena 1994, p. 224).

Secondly, public investments in research decrease the productivity growth differentials between sectors. In the baseline scenario, there were clearly high-tech and low-tech industries in both countries. The benefits of open science policies, through their effect on the probability to innovate at business level, are evident: though productivity differentials still exist, sectoral gains are much more concentrated around a common average than before. Domestic industries tend to follow parallel technological trajectories. Yet, if all resources are concentrated to mission-oriented targets, this raises cross-sectoral productivity differences. A second message out of the experiments is that the productivity *convergence* between sectors is a result of open-science policies. Indeed, even if economic growth is largely driven by the sectors with absolute advantages, or industries most helped by the government, having at least a little flow of open-science investments as percentage of GDP still allows other sectors to survive and innovate, preserving the bio-diversity of the economic fabric.
This result adds a further rationale for the support of basic research by public funds, away from the old-fashioned "market failure" arguments. As clearly summarised by Salter and Martin (2001, p. 528), "These benefits are often subtle, heterogeneous, difficult to track or measure, [...] and should be viewed as a source of new ideas, opportunities, methods and, most importantly, trained problem-solvers". Basically, the building up of learning capabilities is the economic goal and most *visible* outcome of science policy.

Moreover, science policy changes the overall structure of the markets. Monopoly dominated every market in the baseline setting. This is no longer true. Science policy alone is sufficient to break monopolistic chains and triggers competition. Three important effects arise. Firstly, countries de-specialise: their economic activity is more diversified and less concentrated in a lower number of sectors. Still, such results are conditioned to the flow of open science. If a country supports the wrong industries and puts all the eggs in the same basket, this may result in a long-run growth trap, in which the country is anchored to unfavourable development trajectories. By contrast, allocating the eggs in several basket,

i.e., preserving open science for a wide array of sectors, countries still have competitive and active firms in the sectors in which they do not specialise. Open science allows, once more, for the survival of sectors.
The literature sometimes mentions the important role of government-funded research in the creation of new firms. The empirical evidence is rather mixed for the high firm birth rates as university spin-offs are paired with low-growth and high-failure rates (Salter and Martin 2001). Our analysis raises concerns on the trade-off between competition and binding constraints on the financement of innovative search. Government policies reduced per-capita profits, making more difficult to grasp the benefits of open science. The corresponding capital-labour ratio is considerably lower than the benchmark average. Whether this can be a valid explanation for the mixed empirical evidence is a topic that deserves future research in a stand-alone work.

Fourthly, inasmuch as the benefits of broad spectrum S&T policies spread across sectors, our work agrees with the recommendations in European Commission (2018e), Mowery et al. (2010), Soete and Arundel (1993, 1995), among the others. These contributions recognize the growing urgency of the societal challenges raised by the climate change and criticised the popular view according to which national governments should just undertake a new ”Manhattan Project” or a new ”Apollo Program” to cope with that. They believe this policy model as inappropriate in both the merit and the manners, for both programs were managed by federal agencies to achieve a specific technological solution for which the government was the sole customer. By contrast, the interests of many different actors are intertwined in societal issues such as the climate change. Rather than being circumscribed to a relatively short-period horizon, public research and innovation policies should be partnered with important private funds, which takes into consideration cost-effectiveness, ease of operation, and reliability systems for several decades (Mowery et al. 2010).
The analysis developed in our study fully agrees with these recommendations and totally supports the call for a governance structure of public R&D programs to encourage a broad dissemination of scientific research across industries. Behind reducing productivity growth differentials across sectors, open science triggers and fuels the Schumpeterian competition out of which new radical solutions to technological challenges might emerge.
Also, as recognised by official documents of supranational institutions (European Commission 2018a,b,c,d,e, Soete and Arundel 1993), supply-side policies alone are not sufficient. In our framework, as well as in real world, science policies seem not to be able to reorganise and change consumption habits: demand-side policies with citizens’ engagement at the forefront is key to better identify, schedule, and device solutions to meet real and concrete

societal needs.[17]

To conclude, despite our results seem to be robust across the scenarios, some caution is advisable. The financial side of the model is not developed, namely how governments obtain funds for investments, by taxes or debt, is not specified. The lack of a banking system as well constrains perhaps too much firms ability to undertake (radical) innovative search. Additionally, labour supply is fully elastic: a well-recognized benefit from science policies is the flow of skilled graduates which bring a knowledge of recent scientific research to firms, and the ability to solve complex problems therein. Last but not least, the role of world demand has been partially sterilized: its growth was constant. Relaxing these constraints in future research would give us a better picture of the possible patterns that (will) characterize the international economic system in general, and the European Monetary Union in particular, in the next future.

Acknowledgements

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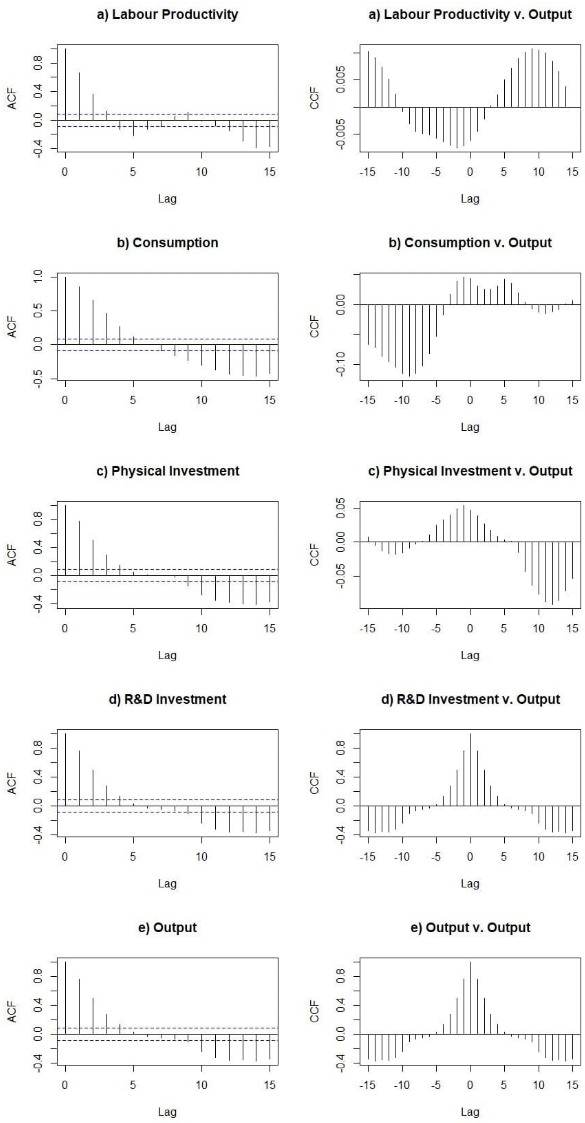
[17] It is important to note that all these policy recommendations, in our opinion, would be useful to fix Europe's structural weakness in its system of scientific research and industry, as argued by Dosi, Llerena and Labini (2006).

A Stylized facts: further statistics

Variable	Country 1	Country 2
GDP	1.277	0.364
Physical Investment	1.277	0.364
R&D Investment	4.454	5.514
Consumption	3.454	5.476
Labour Productivity	2.142	3.233

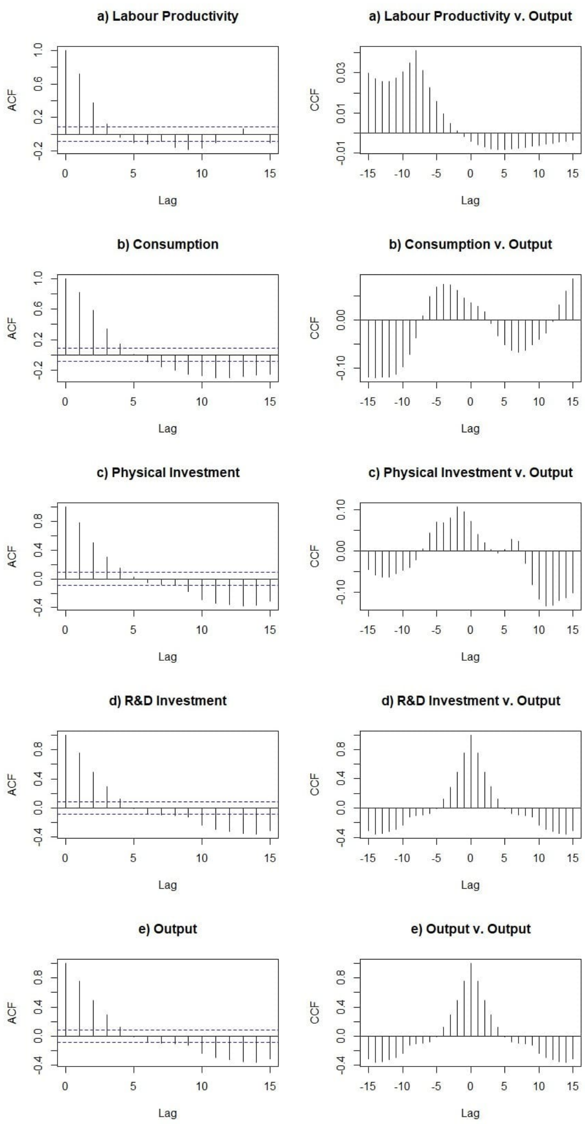
Note: We computed unit-root tests for the first thousand period simulations. The 1% critical values for ADF t is -3.430. We performed regressions with four lagged differences.

Table 14. ADF unit-root test for key macroeconomic series



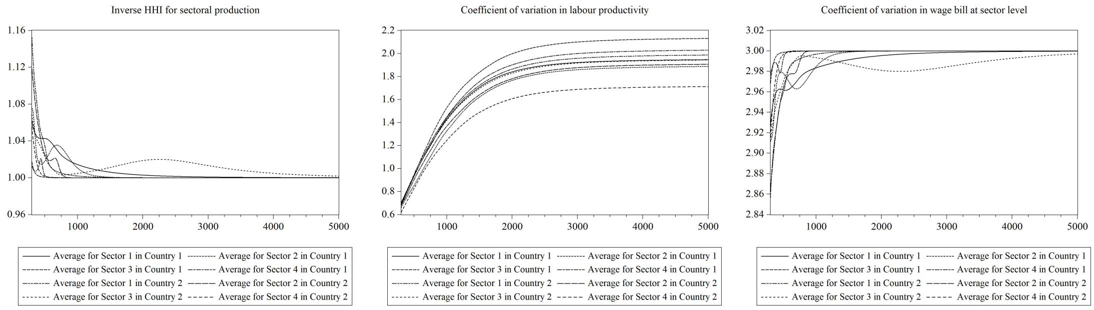
Note: autocorrelation and cross-correlation with output up to 15 lags on the left-hand-side for labour productivity, consumption, physical investment, R&D investment and output. Dashed lines refer to pointwise confidence intervals at 95% significance level. On the right-hand side we report the cross-correlation of these aggregate series with GDP. For any graph, correlations are computed with HP de-trended series; the horizontal axis shows the number of lags and the vertical axis the correlation.

Figure 6. Correlation structures for Country 1



Note: cross-correlation with output up to 15 lags on the left-hand-side for labour productivity, consumption, physical investment, R&D investment and output. Dashed lines refer to pointwise confidence intervals at 95% significance level. On the right-hand side we report the cross-correlation of these aggregate series with GDP. For any graph, correlations are computed with HP de-trended series; the horizontal axis shows the number of lags and the vertical axis the correlation.

Figure 7. Correlation structures for Country 2



Note: we represent average Monte Carlo replications and we have deleted the first 300 hundreds periods both to focus on the long-run stable pattern of the series and to highlight the convergence mechanism.

Figure 8. Specialisation and technological change at sector level

B Further experiments in science policy

Tab. 15 to Tab. 25 present the results of the same experiments when countries pursue *asymmetric* science policies. From a qualitative viewpoint, previous results do still hold. We underline divergence trajectories for both GDP and productivity growth are much stronger in all pairs of experiments. Productivity divergences are now reinforced both between and within countries (Tab. 17 and Tab. 18). At the same time, markets are on average more concentrated, though the dynamics mirror what we have outlined above with related implications for income inequality. Moreover, the only existence of public policies still entails an increase in the portfolio of industries where a country have at least one profit-making domestic firm. Still no remarkable impact on the manner national governments affect consumption patterns by science policies.

B.1 Asymmetric policies: economic growth and structural change

ψ_c , g_c	0.02	0.04	0.06	0.08	0.1
Pushing the technological frontier ahead vs. Creating a position of leadership					
0	0.007***	0.009***	0.005***	0.114***	0.005***
0.3	0.017***	0.011***	0.026***	0.017***	0.068***
0.5	0.054***	0.012***	0.015***	0.013***	0.020***
0.7	0.036***	0.018***	0.024***	0.052***	0.011***
0.9	0.034***	0.008***	0.055***	0.015***	0.016***
1	0.022***	0.025***	0.038***	0.015***	0.038***
Pushing the technological frontier ahead vs. Sustaining/relaunching declining sectors					
0	0.007***	0.009***	0.005***	0.114***	0.005***
0.3	0.007***	0.005***	0.023***	0.008***	0.053***
0.5	0.039***	0.008***	0.012***	0.007***	0.006***
0.7	0.053***	0.016***	0.018***	0.042***	0.007***
0.9	0.032***	0.006***	0.041***	0.006***	0.007***
1	0.010***	0.008***	0.050***	0.004**	0.024***
Creating/sustaining a position of leadership vs. Sustaining/relaunching declining sectors					
0	0.007***	0.009***	0.005***	0.114***	0.005***
0.3	0.053***	0.014***	0.032***	0.012***	0.054***
0.5	0.042***	0.019***	0.017***	0.009***	0.030***
0.7	0.058***	0.031***	0.022***	0.057***	0.023***
0.9	0.042***	0.020***	0.041***	0.020***	0.052***
1	0.029***	0.037***	0.057***	0.016***	0.014***

Note: mean values over 25 replications for the key indicator at Monetary Union level over last 4000 simulation steps. The benchmark scenario considers g_c as null. The corresponding benchmark Monte Carlo average is 0.003 with a standard deviation equal to 0.0028. The significance of the difference between the benchmark configuration and each pair of parameters is computed with a t-test: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 15. Asymmetric policies: coefficient of variation of GDP growth across experiments

ψ_c , g_c	0.02	0.04	0.06	0.08	0.1	0.02	0.04	0.06	0.08	0.1
Pushing the technological frontier ahead vs. Creating a position of leadership										
			Country 1					*Country 2*		
0	1.149	1.125**	1.118**	1.152	1.142	1.157	1.178**	1.188**	1.159	1.165
0.3	1.196***	1.200***	1.211***	1.165	1.181*	1.112**	1.109***	1.100***	1.142	1.122*
0.5	1.148	1.186**	1.187**	1.185**	1.188**	1.158	1.121*	1.121*	1.124	1.116**
0.7	1.170	1.191**	1.179*	1.191**	1.223***	1.139	1.118**	1.340	1.117**	1.088***
0.9	1.198***	1.182*	1.195***	1.206***	1.197***	1.113**	1.130	1.113	1.107***	1.114**
1	1.191**	1.178*	1.155	1.192***	1.187***	1.117**	1.131	1.155	1.119**	1.124
Pushing the technological frontier ahead vs. Sustaining/relaunching declining sectors										
			Country 1					*Country 2*		
0	1.149	1.125**	1.118**	1.152	1.142	1.157	1.178**	1.188**	1.159	1.165
0.3	1.185**	1.194***	1.209***	1.160	1.164	1.122*	1.116**	1.103	1.146	1.140
0.5	1.133	1.185**	1.186**	1.175	1.177	1.173*	1.122*	1.122*	1.134	1.128
0.7	1.168	1.190**	1.166	1.180*	1.222***	1.141	1.119**	1.144	1.128	1.090***
0.9	1.196***	1.180*	1.183**	1.205***	1.188**	1.115**	1.132	1.125	1.108***	1.123*
1	1.183**	1.164	1.150	1.176	1.171	1.125	1.146	1.160	1.135	1.139
Creating a position of leadership vs. Sustaining/relaunching declining sectors										
			Country 1					*Country 2*		
0	1.149	1.125**	1.118**	1.152	1.142	1.157	1.178**	1.188**	1.159	1.165
0.3	1.163	1.162	1.158	1.131	1.142	1.143	1.146	1.154	1.177**	1.163
0.5	1.117**	1.147	1.153	1.123**	1.143	1.190***	1.161	1.153	1.186***	1.164
0.7	1.106***	1.149	1.131	1.148	1.179*	1.206***	1.157	1.178**	1.160	1.130
0.9	1.158	1.160	1.155	1.160	1.147	1.153	1.152	1.150	1.152	1.165
1	1.144	1.131	1.116***	1.150	1.152	1.164	1.177**	1.199***	1.160	1.155

Note: mean values over 25 replications for the key indicator at Country level over last 4000 simulation steps. The benchmark scenario considers g_c as null. The corresponding benchmark Monte Carlo average is 1.154 (sd = 0.071) in Country 1 and 1.147 (sd = 0.070) in Country 2. The significance of the difference between the benchmark configuration and each pair of parameters is computed with a t-test: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 16. Asymmetric policies: Harrodian trade multiplier across experiments

ψ_c , g_c	0.02	0.04	0.06	0.08	0.1
	Pushing the technological frontier ahead vs. Creating a position of leadership				
0	0.867***	0.798***	0.841***	0.782***	0.850***
0.3	1.022***	1.106***	1.761***	1.023***	1.019***
0.5	1.871***	1.093***	1.220***	1.022***	1.240***
0.7	1.156***	1.087***	1.327***	1.214***	1.035***
0.9	1.092***	1.267***	1.113***	1.115***	1.231***
1	1.752***	1.270***	1.149***	1.115***	1.020***
	Pushing the technological frontier ahead vs. Sustaining/relaunching declining sectors				
0	0.867***	0.798***	0.841***	0.782***	0.850***
0.3	0.999***	1.000***	1.710***	1.010***	0.984***
0.5	0.990***	1.042***	1.583***	1.026***	1.005***
0.7	1.007***	1.082***	1.158***	1.210***	1.001***
0.9	1.089***	0.997***	1.049***	1.016***	1.029***
1	1.385***	1.003***	1.049***	0.999***	1.015***
	Creating/sustaining a position of leadership vs. Sustaining/relaunching declining sectors				
0	0.867***	0.798***	0.841***	0.782***	0.850***
0.3	1.070***	1.026***	1.745***	1.002***	0.987***
0.5	1.071***	1.069***	1.010***	1.025***	1.028***
0.7	1.700***	1.127***	1.010***	1.057***	1.256***
0.9	1.111***	1.047***	1.060***	1.147***	1.299***
1	1.014***	2.271***	1.191***	1.007***	1.031***

Note: mean values over 25 replications for the key indicator at Monetary Union level over last 4000 simulation steps. The benchmark scenario considers g_c as null. The corresponding benchmark Monte Carlo average is 0.047 with a standard deviation equal to 0.008. The significance of the difference between the benchmark configuration and each pair of parameters is computed with a t-test: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 17. Asymmetric policies: coefficient of variation of productivity growth between countries across experiments

ψ_c , g_c	0.02	0.04	0.06	0.08	0.1	0.02	0.04	0.06	0.08	0.1
	Pushing the technological frontier ahead vs. Creating a position of leadership									
	Country 1					*Country 2*				
0	0.934*	1.117	1.158	0.940	0.830***	0.789***	0.545***	0.614***	0.898**	0.892**
0.3	0.646***	0.672***	0.475***	0.799***	0.751***	1.403***	1.365***	1.496***	1.072	1.407***
0.5	1.103	0.777***	0.706***	0.703***	0.540***	1.153	1.240**	1.165	1.284***	1.557***
0.7	0.626***	0.929**	0.898**	0.862***	0.345***	1.280***	1.297***	1.171	1.410***	1.580***
0.9	0.593***	0.873**	0.770***	0.473***	0.693***	1.476***	1.196*	1.393***	1.478***	1.368***
1	0.578***	0.765***	0.863***	0.961	0.841***	1.427***	1.315***	1.183*	1.349***	1.331***
	Pushing the technological frontier ahead vs. Sustaining/relaunching declining sectors									
	Country 1					*Country 2*				
0	0.934*	1.117	1.158	0.940	0.830***	0.789***	0.545***	0.614***	0.898**	0.892**
0.3	0.646***	0.672***	0.475***	0.799***	0.751***	1.310***	1.157	1.488***	0.994	1.164
0.5	1.102	0.777***	0.706***	0.684***	0.570***	0.897**	1.141	1.073	1.148	1.312***
0.7	0.626***	0.929*	0.894**	0.868***	0.354***	1.216**	1.175	1.067	1.298***	1.513***
0.9	0.596***	0.873**	0.871***	0.472***	0.687***	1.442***	1.101	1.234**	1.345***	1.235**
1	0.579***	0.766***	0.866***	0.963	0.842***	1.230**	1.060	1.029	1.165	1.241**
	Creating a position of leadership vs. Sustaining/relaunching declining sectors									
	Country 1					*Country 2*				
0	0.934*	1.117	1.158	0.940	0.830***	0.789***	0.545***	0.614***	0.898**	0.892**
0.3	0.995	1.142	0.996	1.104	1.011	1.171	0.872**	1.036	0.649***	0.898**
0.5	1.311***	1.150	1.073	1.148	1.140	0.758***	0.896**	0.826***	0.816***	0.897**
0.7	1.327***	1.331***	1.292***	1.230**	0.834***	0.761***	0.900**	0.809***	1.020	1.233**
0.9	1.044	1.068	1.103	1.053	1.087	1.162	1.029	1.021	0.979	0.996
1	0.975	1.355***	1.358***	1.144	1.036	1.021	0.596***	0.828***	1.042	0.916*

Note: mean values over 25 replications for the key indicator at Country level over last 4000 simulation steps. The benchmark scenario considers g_c as null. The corresponding benchmark Monte Carlo average is 1.061 (sd = 0.371) in Country 1 and 1.054 (sd = 0.367) in Country 2. The significance of the difference between the benchmark configuration and each pair of parameters is computed with a t-test: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 18. Asymmetric policies: coefficient of variation of productivity growth within countries across experiments

ψ_c , g_c	0.02	0.04	0.06	0.08	0.1	0.02	0.04	0.06	0.08	0.1
Pushing the technological frontier ahead vs. Creating a position of leadership										
	Country 1					*Country 2*				
0	2.337***	1.923	1.914	2.213*	2.383***	2.547***	2.974***	2.795***	2.491***	2.496***
0.3	2.721***	2.478***	2.801***	2.257**	2.608***	1.763*	1.669**	1.554***	2.021	1.781
0.5	2.236**	2.510***	2.501***	2.437***	2.736***	2.092	1.768*	1.988	1.714*	1.760*
0.7	2.530***	2.534***	2.245**	2.509***	2.888***	1.953	1.799	1.932	1.886	1.335***
0.9	2.636***	2.396***	2.761***	2.699***	2.543***	1.520***	1.842	1.942	1.494***	1.625***
1	2.732***	2.528***	2.173	2.313***	2.573***	1.959	2.059	2.072	1.766*	1.725**
Pushing the technological frontier ahead vs. Sustaining/relaunching declining sectors										
	Country 1					*Country 2*				
0	2.337***	1.923	1.914	2.213*	2.383***	2.547***	2.974***	2.795***	2.491***	2.496***
0.3	2.613***	2.446***	2.771***	2.226***	2.466***	1.905	1.772	1.587***	2.100	1.993
0.5	2.126	2.509***	2.496***	2.356***	2.613***	2.273**	1.793	2.021	1.829	1.955
0.7	2.515***	2.529***	2.125	2.388***	2.845***	2.013	1.835	2.111	2.055	1.393***
0.9	2.599***	2.383***	2.506***	2.687***	2.449***	1.565***	1.880	2.154	1.530***	1.755*
1	2.670***	2.406***	2.140	2.164	2.368***	2.068	2.240**	2.179	1.980	1.969
Creating a position of leadership vs. Sustaining/relaunching declining sectors										
	Country 1					*Country 2*				
0	2.337***	1.923	1.914	2.213*	2.383***	2.547***	2.974***	2.795***	2.491***	2.496***
0.3	2.368***	2.001	2.208*	1.845	2.116	2.142	2.167	2.105	2.455***	2.341***
0.5	1.881	2.007	2.070	1.804	2.004	2.488***	2.195*	2.411***	2.324***	2.362***
0.7	1.737*	2.111	1.718**	1.889	2.328***	2.617***	2.243**	2.540***	2.403***	1.816
0.9	2.120	2.140	2.034	2.054	2.012	1.994	2.084	2.452***	2.131	2.218*
1	2.250**	1.635***	1.602***	1.934	2.172	2.410***	2.638***	2.517***	2.191*	2.432***

Note: mean values over 25 replications for the key indicator at Country level over last 4000 simulation steps. The benchmark scenario considers g_c as null. The corresponding benchmark Monte Carlo average is 1.973 (sd = 0.627) in Country 1 and 1.978 (sd = 0.626) in Country 2. The significance of the difference between the benchmark configuration and each pair of parameters is computed with a t-test: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 19. Asymmetric policies: inverse Herfindahl index of output across experiments

ψ_c , g_c	0.02	0.04	0.06	0.08	0.1	0.02	0.04	0.06	0.08	0.1
Pushing the technological frontier ahead vs. Creating a position of leadership										
	Country 1					*Country 2*				
0	5.418***	5.495***	5.443***	8.133***	5.457***	5.379***	5.329***	5.331***	5.473***	5.455***
0.3	5.377***	5.437***	5.268***	5.257***	5.373***	8.779***	8.253***	7.879***	7.713***	8.838***
0.5	5.536***	5.356***	5.279***	5.402***	5.354***	8.888***	7.707***	6.651***	8.405***	8.633***
0.7	5.582***	5.392***	5.378***	5.860***	5.272***	7.512***	7.457***	8.771***	8.925***	7.608***
0.9	5.457***	5.374***	5.317***	5.358***	5.266***	7.939***	7.349***	8.993***	6.772***	8.300***
1	5.305***	5.339***	5.647***	5.460***	5.311***	7.855***	8.619***	7.964***	9.212***	9.329***
Pushing the technological frontier ahead vs. Sustaining/relaunching declining sectors										
	Country 1					*Country 2*				
0	5.418***	5.495***	5.443***	8.133***	5.457***	5.379***	5.329***	5.331***	5.473***	5.455***
0.3	5.434***	5.438***	5.256***	5.275***	5.422***	5.494***	5.531***	5.486***	5.321***	6.273***
0.5	5.507***	5.330***	5.250***	5.418***	5.383***	5.639***	5.455***	5.321***	5.400***	5.374***
0.7	6.150***	5.376***	5.439***	5.756***	5.266***	5.350***	5.470***	5.344***	5.482***	5.481***
0.9	5.471***	5.374***	5.379***	5.323***	5.289***	5.534***	5.445***	5.659***	5.515***	5.398***
1	5.309***	5.373***	6.174***	5.507***	5.425***	5.336***	5.296***	5.312***	5.507***	5.552***
Creating a position of leadership vs. Sustaining/relaunching declining sectors										
	Country 1					*Country 2*				
0	5.418***	5.495***	5.443***	8.133***	5.457***	5.379***	5.329***	5.331***	5.473***	5.455***
0.3	8.418***	8.962***	8.189***	6.961***	7.570***	6.845***	5.453***	5.326***	5.163***	6.190***
0.5	8.411***	8.850***	8.134***	7.283***	8.558***	5.524***	5.288***	5.233***	5.212***	5.302***
0.7	7.683***	8.614***	7.940***	8.603***	8.555***	5.142***	5.329***	5.232***	5.300***	5.386***
0.9	9.014***	8.845***	8.739***	8.739***	8.254***	5.450***	5.360***	5.573***	5.333***	5.279***
1	8.045***	8.379***	8.172***	8.891***	8.316***	5.246***	5.332***	5.227***	5.398***	5.276***

Note: mean values over 25 replications for the key indicator at Country level over last 4000 simulation steps. The benchmark scenario considers g_c as null. The corresponding benchmark Monte Carlo log-average is 11.193 (sd = 0.030) in Country 1 and 11.186 (sd = 0.028) in Country 2. The significance of the difference between the benchmark configuration and each pair of parameters is computed with a t-test: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 20. Asymmetric policies: capital-labour ratio across experiments

B.2 Asymmetric policies: market structure, income distribution, and consumption behaviour

ψ_c , g_c	0.02	0.04	0.06	0.08	0.1
Pushing the technological frontier ahead vs. Creating a position of leadership					
0	0.363***	0.387***	0.391***	0.220***	0.334***
0.3	0.424***	0.453***	0.382***	0.355***	0.437***
0.5	0.466***	0.433***	0.360***	0.421***	0.405***
0.7	0.389***	0.450***	0.439***	0.443***	0.395***
0.9	0.426***	0.447***	0.426***	0.428***	0.394***
1	0.397***	0.406***	0.408***	0.499***	0.406***
Pushing the technological frontier ahead vs. Sustaining/relaunching declining sectors					
0	0.363***	0.387***	0.391***	0.220***	0.334***
0.3	0.379***	0.344***	0.347***	0.292***	0.331***
0.5	0.338***	0.377***	0.315***	0.355***	0.303***
0.7	0.341***	0.381***	0.362***	0.373***	0.352***
0.9	0.408***	0.394***	0.359***	0.369***	0.346***
1	0.316***	0.313***	0.316***	0.397***	0.385***
Creating/sustaining a position of leadership vs. Sustaining/relaunching declining sectors					
0	0.363***	0.387***	0.391***	0.220***	0.334***
0.3	0.395***	0.433***	0.367***	0.306***	0.338***
0.5	0.366***	0.375***	0.365***	0.349***	0.348***
0.7	0.336***	0.404***	0.383***	0.390***	0.414***
0.9	0.448***	0.415***	0.388***	0.407***	0.389***
1	0.344***	0.375***	0.387***	0.447***	0.366***

Note: mean values over 25 replications for the key indicator at Monetary Union level over last 4000 simulation steps. The benchmark scenario considers g_c as null. The corresponding benchmark Monte Carlo average is 0.998 with a standard deviation equal to 0.004. The significance of the difference between the benchmark configuration and each pair of parameters is computed with a t-test: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 21. Asymmetric policies: inverse Herfindahl index of market shares across experiments

ψ_c , g_c	0.02	0.04	0.06	0.08	0.1	0.02	0.04	0.06	0.08	0.1
Pushing the technological frontier ahead vs. Creating a position of leadership										
	Country 1					*Country 2*				
0	1.672*	1.746	1.633**	1.613**	1.651**	1.608*	1.550**	1.480***	1.547**	1.433***
0.3	1.520***	1.554***	1.456***	1.600***	1.513***	1.706	1.827	1.866	1.617*	1.643
0.5	1.652**	1.599***	1.507***	1.485***	1.451***	1.738	1.577**	1.599**	1.680	1.803
0.7	1.523***	1.617**	1.625**	1.530***	1.435***	1.677	1.657	1.622*	1.770	1.806
0.9	1.528***	1.643**	1.445***	1.515***	1.501***	1.686	1.760	1.716	1.821	1.681
1	1.518***	1.569***	1.656**	1.589***	1.522***	1.687	1.612*	1.744	1.677	1.603*
Pushing the technological frontier ahead vs. Sustaining/relaunching declining sectors										
	Country 1					*Country 2*				
0	1.672*	1.746	1.633**	1.613**	1.651**	1.608*	1.550**	1.480***	1.547**	1.433***
0.3	1.548***	1.568***	1.463***	1.610*	1.544***	1.667	1.730	1.827	1.591**	1.592**
0.5	1.687	1.600***	1.509***	1.501***	1.473***	1.613*	1.522***	1.623*	1.608*	1.740
0.7	1.530***	1.619**	1.660*	1.548***	1.437***	1.639	1.627*	1.596**	1.680	1.837
0.9	1.540***	1.649**	1.500***	1.519***	1.514***	1.660	1.726	1.642	1.760	1.643
1	1.531***	1.601***	1.671*	1.624**	1.577***	1.630*	1.537***	1.653	1.642	1.531***
Creating a position of leadership vs. Sustaining/relaunching declining sectors										
	Country 1					*Country 2*				
0	1.672*	1.746	1.633**	1.613**	1.651**	1.608*	1.550**	1.480***	1.547**	1.433***
0.3	1.638**	1.716	1.567***	1.753	1.622*	1.591**	1.490***	1.651	1.517***	1.482***
0.5	1.692	1.643**	1.681	1.733	1.601***	1.548**	1.470***	1.489***	1.447***	1.592**
0.7	1.734	1.713	1.835	1.540***	1.595***	1.470***	1.536***	1.518***	1.566**	1.696
0.9	1.613**	1.618**	1.704	1.632**	1.682*	1.602*	1.658	1.549**	1.584**	1.564**
1	1.559***	1.775	1.818	1.677	1.711	1.607*	1.493***	1.535***	1.603*	1.535***

Note: mean values over 25 replications for the key indicator at Country level over last 4000 simulation steps. The benchmark scenario considers g_c as null. The corresponding benchmark Monte Carlo average is 1.822 (sd = 0.416) in Country 1 and 1.779 (sd = 0.449) in Country 2. The significance of the difference between the benchmark configuration and each pair of parameters is computed with a t-test: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 22. Asymmetric policies: coefficient of variation of wage bill within countries across experiments

ψ_c , g_c	0.02	0.04	0.06	0.08	0.1
Pushing the technological frontier ahead vs. Creating a position of leadership					
0	0.198**	0.195**	0.199**	0.384***	0.220**
0.3	0.233***	0.244***	0.242***	0.273***	0.260***
0.5	0.214**	0.212**	0.270***	0.278***	0.230***
0.7	0.220**	0.217**	0.267***	0.243***	0.290***
0.9	0.253***	0.227**	0.249***	0.240***	0.269***
1	0.213**	0.218**	0.232***	0.272***	0.279***
Pushing the technological frontier ahead vs. Sustaining/relaunching declining sectors					
0	0.198**	0.195**	0.199**	0.384***	0.220**
0.3	0.239***	0.279***	0.243***	0.281***	0.256***
0.5	0.253***	0.235***	0.256***	0.283***	0.256***
0.7	0.237***	0.227***	0.265***	0.263***	0.273***
0.9	0.259***	0.239***	0.256***	0.264***	0.268***
1	0.233***	0.235***	0.264***	0.267***	0.311***
Creating/sustaining a position of leadership vs. Sustaining/relaunching declining sectors					
0	0.198**	0.195**	0.199**	0.384***	0.220**
0.3	0.252***	0.269***	0.243***	0.273***	0.274***
0.5	0.279***	0.287***	0.229***	0.268***	0.261***
0.7	0.250***	0.267***	0.258***	0.244***	0.275***
0.9	0.235***	0.257***	0.233***	0.287***	0.246***
1	0.242***	0.289***	0.256***	0.265***	0.236***

Note: mean values over 25 replications for the key indicator at Monetary Union level over last 4000 simulation steps. The benchmark scenario considers g_c as null. The corresponding benchmark Monte Carlo average is 0.108 with a standard deviation equal to 0.218. The significance of the difference between the benchmark configuration and each pair of parameters is computed with a t-test: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 23. Asymmetric policies: coefficient of variation of wage bill between countries across experiments

ψ_c , g_c	0.02	0.04	0.06	0.08	0.1	0.02	0.04	0.06	0.08	0.1
			Pushing the technological frontier ahead vs. Creating a position of leadership							
			Country 1					*Country 2*		
0	2.980	2.979	2.979	2.972***	2.982	2.981	2.984**	2.985***	2.972	2.983*
0.3	2.989***	2.988***	2.985***	2.985***	2.991***	2.980	2.981	2.973***	2.982	2.979
0.5	2.986***	2.984**	2.982	2.989***	2.984**	2.982	2.978	2.977	2.982	2.976
0.7	2.977	2.985***	2.984**	2.983*	2.986***	2.980	2.978	2.980	2.980	2.975*
0.9	2.980	2.984***	2.985***	2.980	2.982	2.976	2.980	2.976	2.972***	2.975*
1	2.986***	2.986***	2.974**	2.978	2.911***	2.979	2.981	2.980	2.982	2.982
			Pushing the technological frontier ahead vs. Sustaining/relaunching declining sectors							
			Country 1					*Country 2*		
0	2.980	2.979	2.979	2.972***	2.982	2.981	2.984**	2.985***	2.972	2.983*
0.3	2.984**	2.983*	2.985***	2.982	2.984**	2.979	2.978	2.974**	2.981	2.976
0.5	2.980	2.983*	2.982	2.983*	2.983	2.979	2.977	2.978	2.979	2.978
0.7	2.980	2.984**	2.979	2.979	2.987***	2.981	2.978	2.980	2.980	2.976
0.9	2.982	2.983*	2.984**	2.979	2.983*	2.978	2.979	2.978	2.972***	2.978
1	2.983*	2.981	2.976	2.983*	2.982	2.978	2.980	2.981	2.981	2.978
			Creating a position of leadership vs. Sustaining/relaunching declining sectors							
			Country 1					*Country 2*		
0	2.980	2.979	2.979	2.972***	2.982	2.981	2.984**	2.985***	2.972	2.983*
0.3	2.978	2.982	2.982	2.979	2.981	2.977	2.982	2.979	2.984**	2.981
0.5	2.979	2.974**	2.977	2.979	2.979	2.981	2.972***	2.978	2.984**	2.973***
0.7	2.971***	2.982	2.975*	2.975*	2.985***	2.983*	2.982	2.982	2.981	2.981
0.9	2.976	2.981	2.981	2.980	2.972***	2.978	2.982	2.979	2.979	2.978
1	2.976	2.976	2.973***	2.984**	2.979	2.979	2.977	2.984**	2.988***	2.980

Note: mean values over 25 replications for the key indicator at Country level over last 4000 simulation steps. The benchmark scenario considers g_c as null. The corresponding benchmark Monte Carlo average is 2.979 (sd = 0.010) in both Countries. The significance of the difference between the benchmark configuration and each pair of parameters is computed with a t-test: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 24. Asymmetric policies: inverse Herfindahl index of consumption shares across experiments

ψ_c , g_c	0.02	0.04	0.06	0.08	0.1	0.02	0.04	0.06	0.08	0.1
	Pushing the technological frontier ahead vs. Creating a position of leadership									
	Country 1					*Country 2*				
0	1.170	1.171	1.171	1.176***	1.169	1.169	1.166***	1.166***	1.171	1.168*
0.3	1.163***	1.164***	1.166***	1.166***	1.162***	1.170	1.170	1.175*	1.168*	1.171
0.5	1.165***	1.167**	1.169	1.163***	1.167**	1.169	1.172	1.172	1.168*	1.173
0.7	1.172	1.166***	1.167**	1.168*	1.165***	1.170	1.172	1.170	1.170	1.174*
0.9	1.170	1.167**	1.166***	1.170	1.169	1.173	1.170	1.173	1.176***	1.174*
1	1.165***	1.166***	1.175**	1.164***	1.161***	1.171	1.169	1.170	1.169	1.168*
	Pushing the technological frontier ahead vs. Sustaining/relaunching declining sectors									
	Country 1					*Country 2*				
0	1.170	1.171	1.171	1.176***	1.169	1.169	1.166***	1.166***	1.171	1.168*
0.3	1.167**	1.168*	1.166***	1.169	1.167**	1.171	1.172	1.175**	1.169	1.173
0.5	1.170	1.168*	1.168*	1.168*	1.168*	1.171	1.172	1.172	1.171	1.171
0.7	1.170	1.167**	1.171	1.171	1.165***	1.169	1.172	1.170	1.170	1.173
0.9	1.168*	1.168*	1.167**	1.171	1.168*	1.172	1.171	1.172	1.176***	1.172
1	1.168*	1.169	1.173	1.168*	1.168*	1.171	1.170	1.169	1.170	1.172
	Creating a position of leadership vs. Sustaining/relaunching declining sectors									
	Country 1					*Country 2*				
0	1.170	1.171	1.171	1.176***	1.169	1.169	1.166***	1.166***	1.171	1.168*
0.3	1.171	1.169	1.169	1.171	1.169	1.173	1.168*	1.171	1.167*	1.170
0.5	1.171	1.175**	1.175**	1.171	1.171	1.169	1.177***	1.172	1.167**	1.176***
0.7	1.177***	1.169	1.174*	1.174*	1.167**	1.168*	1.169	1.169	1.169	1.169
0.9	1.173	1.169	1.169	1.170	1.176***	1.172	1.169	1.171	1.171	1.171
1	1.173	1.173	1.176***	1.167**	1.171	1.171	1.172	1.167**	1.164***	1.170

Note: mean values over 25 replications for the key indicator at Country level over last 4000 simulation steps. The benchmark scenario considers g_c as null. The corresponding benchmark Monte Carlo average is 1.171 (sd = 0.007) in both Countries. The significance of the difference between the benchmark configuration and each pair of parameters is computed with a t-test: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 25. Asymmetric policies: coefficient of variation for consumption shares across experiments

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