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The North-South divide: Sources of divergence, policies for convergence☆

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Abstract

Building on the labour-augmented K+S model framework, we analyse the Italian North-South divide by means of an agent-based model (ABM) endogenously reproducing the divergence between two artificial macro-regions. The latter are characterised by identical initial conditions in terms of productive and innovation structures, but different labour market organisations. We identify the role played by these different arrangements on the possible divergence across the two regions. We found that divergences in the labour market reverberate into asymmetric productive performance due to negative reinforcing feedback loop dynamics. We then compare alternative mitigation policies by showing that schemes increasing machine renewal and replacement investment are the most effective in fostering convergence.

JEL classification: C63; J3; E24; O1

Keywords: Agent-based models; Technology gap; Labour market

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1. Introduction

The Italian North-South divide has been a long-lasting phenomenon since country unification, temporarily reduced in the two decades after WWII, the so-called Italian "economic miracle", and then resurged again (Papagni et al., 2021). More recently, the sovereign debt and the pandemic crises have fuelled the territorial gap while the productive-structure divergence is crystallising, with northern regions responsible for the majority of the domestic production and the rising geographical inequalities. Although being a textbook case, the Italian economy is not the only one characterised by such divides: it is a similar case of the coastal versus inner areas in the US or China, the South versus the North in Great Britain, and the West and the East in Germany, just to mention a few cases. As such, the analysis of territorial divergence is *per se* a relevant object of investigation.

With reference to the Italian gap, so far, the literature has mostly focused on sources of divergence deriving from asymmetries in productive performance — e.g., per capita GDP — and their negative impact on inequality and regional disparities among northern and southern areas (Daniele & Malanima, 2014; Felice, 2019; Viesti et al., 2011). In addition, territorial divides have usually been studied from an empirical standpoint, mostly through historical lenses. In this paper, we take an alternative route by drawing on the complex system approach and agent-based modelling. We evaluate a particular source of divergence: the different (de) regulation level of the labour markets acting as a first order channel fuelling, in turn, the productive performance divergence. On the empirical ground, corroborating our modelling hypothesis, the concentration of temporary and part-time contracts, the reduction in working hours, and the wage stagnation have been more pronounced in southern Italian regions (Cetrulo et al., 2022), although transformations in labour-market institutions pertain to the entire Italy.

Building upon the labour-augmented Schumpeter Meeting Keynes (K+S) modelling framework (Dosi et al., 2010, 2017; Dosi, Pereira et al., 2020), we address the analysis of the North-South divide by means of a theoretical agent-based model (ABM) able to endogenously reproduce the observed divergence and some associated causal mechanisms. An ABM is a tool adequate to deeply organise our understanding on how a complex system operates and, so, helps us on the evaluation of alternative policy responses to economic change. In this paper we investigate on the possible contribution of the labour-market institutions to the regional divergence, even if these are not the only ones — or the most — relevant to the problem. The proposed model represents two macro-regions characterised by identical initial conditions in terms of productive and innovation structures, but different labour market organisations. From this set-up we observe that more stable industrial relations, employment stability, and opportunity of wage growth characterise the more regulated North in comparison to the more "flexible" South. Given the similar initial conditions of the two macro-regions, we can identify the role played by the different labour institutions on the divergent outcome. We do find that differences in labour market organisation may result in long-term asymmetry of productive performance. Analysing the model results, this outcome is mainly due to reinforcing feedback loops over time.

After studying the extent to which the divide might be accounted by propagation of effects from the labour market, we compare three experiments implementing alternative policies in the South in order to evaluate possible paths of convergence. The considered experiments include (i) an investment-incentive policy to accelerate new technology diffusion by machine replacement, (ii) a training policy directed to increase workers productive skills, and (iii) a wage-indexation policy increasing the weight of firm-level productivity growth to wages gains. These

experiments try to capture some policy recommendations frequently proposed by the literature. They are schematic, on purpose, to allow disentangling the contributions of each component of usual policy mixes.

According to our results, the investment-incentive policy seems the most effective to foster convergence by allowing the catching up of South firms. At the opposite end, the decentralised wage indexation policy is mostly irrelevant for this purpose. In between both, the skill-enhancing policy may narrow the inter-regional gap by increasing the exit rate of low-productivity firms. Overall, experiments highlight the relevance of policies targeted to improve the productivity of both capital equipment and labour.

The paper is organised as follows. Section 2 discusses sources of divergence among regions/countries characterised by different development patterns, and potential policy strategies to circumvent it, with a focus on the Italian case. In Section 3 we present the proposed agent-based model. Section 4 shows the diverging structure outcomes of our two-region set-up. Finally, in Section 5 we compare alternative convergence policies at the macro and micro level. Section 6 concludes the paper.

2. Sources of divergence and mitigation policies

The study of divergences across countries and regions is at the core of economic development theories, looking at the heterogeneous macroeconomic and sectoral outcomes determined by the industrialisation process (Kuznets, 1955), and their consequences on income distribution, usually characterised by the so-called inverted U-shape Kuznets curve (Williamson, 1965). However, persistent regional divides may follow even after productive convergence is reached, therefore presenting an S-shape curve pattern (see, among others, Amos, 1988 and Daniele & Malanima, 2014).

Alternative theoretical perspectives have addressed the problem of geographical divergence. The structuralist approach highlights the importance of asymmetric productive compositions, patterns of technological learning, and specialisation between advanced and developing economies (Cimoli, 1988; Cimoli & Dosi, 1995; Cimoli & Porcile, 2014; Dosi et al., 2009; Dosi, Riccio et al., 2021). The core-periphery approach studied asymmetries among member states within the European Monetary Union (EMU) (Celi et al., 2019; Landesmann et al., 2015; Storm & Naastepad, 2015), and uneven development along international value chains in general (Pavlínek, 2018), drawing from the dependency theory (Prebisch, 1950). Another strand of literature analysed the socio-economic divide among regions of (relatively) recently unified countries, such as Italy (Daniele & Malanima, 2011) and Germany (Blum, 2013, 2019; Boltho et al., 2018).

The Italian case is indeed relevant for the analysis due to both the weaker economic performance when compared to other European countries, and the high persistence of divergence within the country (Svimez, 2019, 2020). This remains true even after considering the accelerated growth and relative convergence experienced in the 1950-1970 decades (Daniele & Malanima, 2011; Viesti et al., 2011). Since the national unification (1861), the Italian productive fabric has been characterised by strong heterogeneity due to different degrees and paces of industrialisation between northern/central and southern areas (the so-called “Mezzogiorno”). A crucial role has been played by the country’s structural change process, with three different phases of growth and development identified by economic historians. The first phase — from 1861 to the post-World War II — was characterised by the intensive shift from agriculture to manufacturing in the northern/central regions — especially in the North-West (the so-called

"industrial triangle" covering Milan-Turin-Genoa) — and the slower or incomplete industrialisation of the South (Federico & Toniolo, 1991; Fenoaltea, 2005). The second phase — the three decades after WWII (the Italian "economic miracle") — recorded an exceptional period of convergence between the North/Centre and the South (Paci & Pigliaru, 1997). The third phase — from 1980 onwards — experienced the progressive shift from manufacturing to service sector (tertiarization), based on heterogeneously developed sectoral structures, with the concentration of more productive services in the northern/central regions, and a widening again of the North-South gap (Capasso et al., 2008; Daniele & Malanima, 2011).

The deep roots of the Italian divide trace back to the post-unification period but persist until the more recent economic downturns. The severity of the intertwined crises experienced by the Italian economy during the last decades (Felice et al., 2019) — i.e., the productivity slowdown, the fiscal crisis, the Great Recession, and the pandemic — have been reinforced by the institutional set-up, the weak investment in research and innovation, the lack of strategic planning, and the abandonment of industrial and upgrading policies (Dosi, Fanti et al., 2020; Dosi et al., 2021; Felice et al., 2019).

So far, the literature has mainly focused on the Italian divergence in terms of productive performance — e.g., per-capita GDP — and its negative impact on inequality and regional disparity (Daniele & Malanima, 2014; Viesti et al., 2011). However, a less investigated channel for the gap goes in the opposite direction, that is from inequality drivers, such as asymmetries in the labour market, to productive performance disparity. On this ground, Svimez (2019) discusses how the increasing trend of socio-economic inequality associated with the higher poverty risk and the worse working conditions have marked the southern region in Italy during the last twenty years. Indeed, this area recorded a higher share of poor workers on the workforce (26.6%) and a higher (and increasing) school-dropout rate (18.8%) when compared to the North/centre (11.7%). In addition, gender asymmetries are significantly stronger. Cetrulo et al. (2022) highlight how divergence in the Italian labour market across geographical areas is a stylised fact characterising the last thirty-five years. Notably, the introduction of the first labour market "flexibilization" reform (*Legge Treu*) represents a turning point for the territorial divergence. This occurred as a result of the progressive use of temporary and part-time contracts in southern regions, reducing the overall individual working time, and therefore the weekly wage (ibid.). In addition, the shares of jobs remained roughly stable across geographical areas except the North-West, recording a slight decline.

The recent socio-economic crisis due to the COVID-19 pandemic has further revealed the North-South divergence in terms of capacity of absorbing shocks. Pre-existing divides, such as income and wealth distribution, gender disparity, living conditions, and sectoral heterogeneity, have amplified the pandemic shock as acknowledged by Svimez (2020), who devoted special attention to the labour market outcomes. This report highlights that consequences of the pandemic on employment, income vulnerability, and unemployment risk have been harsher for the Italian southern regions, in particular for migrant and temporary workers, with a decrease of household disposable income of 9.9%.

Given the existence of geographical divergence, which policies could foster economic convergence? In theoretical terms, we identify at least two main approaches for this catching-up process, and two categories of related policies: *market-* and *institutional-based*.

Among market-based policies, usual examples are (i) foreign direct investment (FDI) and productive off-shoring from developed to developing countries aimed at increasing the output capacity of receiving countries (Dutt, 1997, 1998); (ii) flexibilization and liberalisation of factors of production in developing areas, particularly labour, aimed at favouring mobility

(Clemens, 2009, 2010; Faini, 1996), or, alternatively but on the same theoretical grounds, decentralised labour-market regimes favouring firm-level, direct firm-worker, wage bargaining and wage-to-productivity indexation (Dustmann et al., 2014). On this ground, Boeri et al. (2021) recently advance a revival of flexible wage systems allowing for local bargaining as a policy tool capable to address the higher non-employment and productivity nexus. In particular, they ascribe the lower employment rates and weaker productivity performance of southern Italian regions to the constraint to wage reduction faced by firms operating in those areas, due to the nationwide wage bargaining system, when compared to the German case. Thus, by comparing West-East Germany and North-South Italy wage and productivity differentials, the authors conclude that the latter would benefit from a German-type flexible local bargaining. Based on ideal and isolated market operation, this kind of policy is often rooted on the principle that catching-up is an automatic process driven by market-price adjustments and firms' cost-reduction strategies aimed at enhancing the productive performance in less developed regions or countries (Cimoli & Dosi, 1995; Dosi et al., 1994).

Alternatively, and rooted on the evolutionary theory of economic development, institutional-based strategies propose a set of complementary policy tools: (i) innovation-oriented policies aimed at creating or improving National and Sectoral Innovation Systems (NIS/SIS) broadly defined (Freeman, 2002; Lundvall, 1992); (ii) medium and long-term direct and targeted industrial policies nurturing the development of productive capabilities, risky investments in innovative projects, disruptive and imitative behaviours of firms in upstream sectors of the production ladder, physical capital investments in downstream sectors, and skills upgrading and training programmes (Dosi et al., 2009); and (iii) public subsidies and investment plans oriented towards the convergence of falling-behind regions.

Back to the Italian case, public investment and subsidies have been at the core of the convergence policies implemented in Italy since the 1950's. On this ground, the combination of the agrarian reform and the institution of the Southern Development Fund (*Cassa del Mezzogiorno*) in 1950 have crucially driven the process of socio-economic convergence between southern and northern regions during the Italian "economic miracle" (Daniele & Malanima, 2011). In this period, public investment programmes in capital-intensive sectors (such as chemistry and steel industry), together with the increasing capital accumulation process, contributed to enrich the production capacity and bolstered the industrialisation of the South (Clark, 2014). Nevertheless, the prevalence of small and medium enterprises (SMEs) operating in isolated industrial districts undermined the industrial development process of the Mezzogiorno, leading to an incomplete (or "soft") industrialisation — the so-called *cathedrals in the desert* — unable to promote a genuine convergence. At the end of the 1970's, the country was divided into "three Italies", the industrialised North — especially the North-West —, the few industrial districts in the South, and the rest of the Mezzogiorno (Bagnasco, 1977). Since the mid-1970's, the combination of negative external shocks (e.g., the stagflation), the progressive structural change from manufacturing to service sectors, and the turn in the national politics — cutting public investment for the South development from 13% during the seventies to 8% of the Italian GDP (Daniele & Malanima, 2011) —, turned the convergence process into a halt, paving the way for the persistent North-South gap until the Great Recession (2007–08) (Lagravinese, 2015) and the pandemic crisis (Dosi, Fanti et al., 2020; Svimez, 2019, 2020). Even though structural EU funds aimed at promoting regional convergence have been recognised as a crucial policy tool (Aiello & Pupo, 2012), indeed during the last decades the North-South gap in Italy has been dramatically and persistently amplified.

Looking ahead, in the aftermath of the pandemic crisis public investments meant to cure territorial divergences are part of the Italian Recovery and Resilience Plan (*Piano Nazionale di Ripresa e Resilienza*, PNRR), the national programme for the implementation of the Next Generation EU recovery plan. On this ground, 40% of the entire plan budget (82.4 billion euros) should be devoted to investments for the economic development of the South, the "sick of Italy". Indeed, sources of divergence and policies of convergence of the North-South gap represent a crucial element to undertake sustainable and virtuous development trajectories in the next future.

3. The model

We now describe the agent-based model (ABM) proposed to account for the North-South divide. The model is built upon the labour-augmented Schumpeter Meeting Keynes (K+S) model, a theoretical, general disequilibrium, stock-flow consistent ABM (Dosi et al., 2017). The K+S family of models is characterised by two dynamically coupled domains: an endogenous growth process driven by the adoption and diffusion of innovations (the Schumpeterian engine), and an aggregate demand process driven by firms' investment and workers' consumption (the Keynesian engine). ABMs differ from empirical models because they are not addressed to make forecasts about the future. Conversely, they are purported on clarifying how the many components of complex systems interact, shedding light on how macro-regularities are interconnected with micro-behaviours. This capability makes the ABM an excellent tool to *compare* alternative scenarios, also evaluating the effect of different policy schemes on the micro and macroeconomic realm.

Fig. 1 describes the structure of the K+S model. It is populated by heterogeneous workers/consumers, capital- and consumption-good firms, banks, plus the central bank and the government.[1]

As the main base model has been described in details in Dosi et al. (2017), we only present here the key equations governing the agents' behaviour involved in the processes driving the divergence between our artificial regions.

3.1. Technical change, production, and investment

Capital-good firms spend in R&D and hire workers to build heterogeneous machines. In turn, consumption-good firms buy machines and employ labour to produce. New generations of machines increase consumption-good firms' productivity.

The technology of capital-good firm i is defined as (A_i^τ, B_i^τ). A_i^τ is the labour productivity of the machine when used by a client consumption-good firm to produce. B_i^τ is the labour productivity of firm i to build the machine. The superscript τ denotes the machine technology vintage.[2] Firm i spends in R&D a fraction of the current revenue hiring workers to perform it. Firms split the R&D workers between innovation and imitation activities. Innovation is modelled as a two-step process. The first step draws whether a firm obtains or not access to an

[1] The model code and a user-friendly IDE are freely accessible at https://github.com/SantAnnaKS/LSD. The model can be also run on-line at https://models.growinpro.eu/ks-labor-icc21, no download or installation required.

[2] For consistency, one machine, irrespective of the technological vintage, always produce the same fixed quantity $m_2 \in \mathbb{R}^*_+$ of consumption goods per time unit. Superior technologies reduce the amount of labour required to produce the same m_2 goods at any time t.

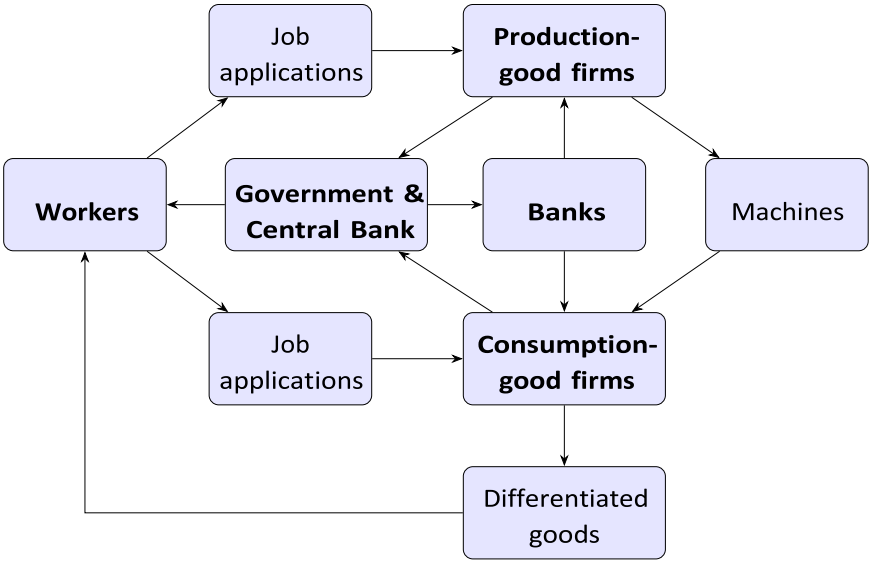

Figure 1. The model overall structure (bold text indicates the model's agents).

innovation with probability proportional to the number of workers allocated to innovative R&D. Then, if firm i successfully innovates, it draws the potential productivities (A_i^{in} and B_i^{in}) of new machines embodying the technology. The imitation process also follows a two-step procedure, but in the second stage firm i may copy a technology $(A_i^{im}, B_i^{im}) = (A_h^{\tau}, B_h^{\tau})$ from a close competitor firm h. Considering the existing machine vintage, and the potential innovation and imitation opportunities, if any, firm h selects the technology to produce in the current period. Finally, capital-good firms set prices using a fixed mark-up rule over unit costs, which depend only on firm-level wage $w_{i,t}$ and productivity $B_{i,t}$, and inform current clients plus a set of potential new ones of the individual prices and productivities of their respective machines.

Firms in consumption-good sector do not conduct R&D, instead they access new technologies incorporating new machines to their existing capital stock, composed by equipment from various vintages acquired from capital-good firms. Consumption-good firm j combines capital and labour in order to produce a single, quality-differentiated good, under constant returns to scale. The expected demand of firm j is driven by myopic demand expectations:

$$D_{j,t}^{e} = g(D_{j,t-1}, D_{j,t-2}, D_{j,t-h}), \quad 0 < h < t, \tag{1}$$

where $D_{j,t-h}$ is the actual demand faced at time $t-h$. g: $\mathbb{R}^h \to \mathbb{R}_+$ is the expectation function, an unweighed moving average over 4 periods. The desired production, considering the actual inventories $N_{j,t}$ from previous period and the desired expectation slack $\iota \in \mathbb{R}_+$, is:

$$Q_{j,t}^{d} = (1 + \iota)D_{j,t}^{e} - N_{j,t-1}. \tag{2}$$

If the desired production is higher than the current capital potential output, firms invest in new machines to expand productive capacity. Also, consumption-good firms may substitute old machines according to a payback-period rule. New replacement machines are evaluated by the ratio between the price of new machine $p^*_{i,t}$ and the corresponding cost savings when operating:

$$\frac{p^*_{i,t}}{w_{j,t-1}\left(\frac{1}{A_i^\tau} - \frac{1}{A^*_{i,t}}\right)} \leq b, \tag{3}$$

whenever the ratio is lower than $b \in \mathbb{R}^*_+$, a parameter, the corresponding machine vintage becomes candidate for substitution. $w_{j,t}$ is firm j current average wage, A_i^τ is the existing machine productivity, and $A^*_{i,t}$, the new machine one. Total firm investment, including expansion and substitution, must be funded by retained past profits or, up to a certain limit, by bank loans, being constrained otherwise.

Firm j effective productivity $A_{j,t}$ results from the employed vintages of machines and the worker-level productivity $A_{\ell,t}$ when operating the designated vintage and the number of workers $L_{j,t}$ allocated:

$$A_{j,t} = \frac{1}{L_{j,t}} \sum_{\ell \in \{L_{j,t-1}\}} A_{\ell,t}. \tag{4}$$

Consumption-good heterogeneous prices are also set based on a variable mark-up rule over labour costs, which depend only on productivity $A_{j,t}$ and wage $w_{j,t}$ at the firm j level. Mark-ups are adjusted following market shares, by raising (lowering) mark-up when share expands (shrinks). Consumption goods are sold in an imperfect-information market where consumers switch gradually to the most competitive producer, considering prices and quality, modelled as a replicator dynamics: more competitive firms expand, less apt ones shrink and eventually close down.

3.2. Worker skills, search-and-hire, and wage determination

The skill level of worker ℓ evolves over time as a multiplicative process:

$$s_{\ell,t} = \begin{cases} (1 + \tau_T) s_{\ell,t-1} & \text{if employed in } t-1 \\ \frac{1}{1+\tau_U} s_{\ell,t-1} & \text{if unemployed in } t-1 \end{cases}, \tag{5}$$

where $(\tau_T, \tau_U) \in \mathbb{R}^2_+$ are parameters governing the learning rate. Worker has a fixed working life, retires after a number of periods T_r, and is replaced by a new one with skills equal to the minimum among employed workers. Skills define worker individual (potential) productivity:

$$A_{\ell,t} = \frac{s_{\ell,t}}{\bar{s}_t} A_i^\tau, \tag{6}$$

being $\bar{s}_t$ the average overall skill level and A_i^τ the standard notional productivity of the specific machinery vintage the worker operates. The weighted-average of workers skills employed in production by firm j also defines the notional product quality which, together with firm price, drives consumer choice.

The labour market is modelled as a decentralised, imperfect information, search-and-hire process between workers and firms. Workers search for jobs sending applications to a random subset of possible employers. Larger firms have a proportionally higher probability of receiving applications. Firms can only hire workers among the applicants for jobs. Firms observe worker skills and (possibly) wage requests only on the applications they effectively get, while workers are aware just about the wage offers they receive as answer to a previous application, if any.

There is just one bargaining round between workers and firms per period: based on the received applications, firms may offer a wage to a number of applicants, who may accept or not.

The aggregate labour supply is fixed. When submitting job applications, workers inform of their skill level, and a non-binding wage request:

$$w^r_{\ell,t} = \begin{cases} w_{\ell,t-1}(1+\epsilon) & \text{if employed in t-1} \\ \max\left(\frac{1}{T_s}\sum_{h=1}^{T_s} w_{\ell,t-h},\ w^u_t\right) & \text{if unemployed in t-1} \end{cases}. \tag{7}$$

$w_{\ell,t}$ is the received wage (zero if unemployed), and $\epsilon \in \mathbb{R}_+$ is a parameter. Unemployed workers have a shrinking wage request that accounts for a fixed wage history time span $T_s \in \mathbb{N}_*$, a parameter. Workers have also a reservation wage represented by the unemployment benefit w^u_t paid by the government, if available. Wage requests may be considered or not by firms, and workers may accept wage offers that are inferior to it.

The aggregate labour demand depends on the opening and closing of job positions by employers. Firms in both sectors are able to hire and fire workers according to the individual desired output $Q^d_{i|j,t}$, i representing a capital-good firm, or j, a consumption-good one. So, firm labour demand $L^d_{i|j,t}$ is determined by:

$$L^d_{i|j,t} = \frac{Q^d_{i|j,t}}{B_{i,t}|A_{j,t}}, \tag{8}$$

$B_{i,t}$ is the productivity of capital-good firm i, or $A_{j,t}$, the one of consumption-good firm j. Firing and hiring transaction costs are not considered. Firms decide whether to hire or fire workers according to the expected worker gap to the previously employed workforce $L_{i|j,t-1}$:

$$\Delta L^d_{i|j,t} = L^d_{i|j,t} - L_{i|j,t-1}. \tag{9}$$

If the gap is positive, new workers are (tentatively) hired, and conversely.

When hiring, firm i or j gets a fraction of the total worker applications, which may be higher or lower than $\Delta L^d_{i|j,t}$. In this case, a wage offer $w^o_{j,t}$ is presented up to this number of applicants:

$$w^o_{j,t} = w^o_{j,t-1}\left(1 + \psi_2\frac{\Delta A_t}{A_{t-1}} + \psi_4\frac{\Delta A_{j,t}}{A_{j,t-1}}\right), \qquad \psi_2 + \psi_4 \le 1, \tag{10}$$

being A_t the aggregate labour productivity, Δ the time difference operator, and $(\psi_2, \psi_4) \in \mathbb{R}^2_+$ parameters. Capital-good firms follow the wage offers from top-payers in the consumption-good sector. Firms favour workers that would accept the wage offer, potentially considering the wage $w^r_{\ell,t}$ requested by workers, if any. $w^o_{j,t}$ is upper bounded to the break-even wage (zero unit profits myopic expectation). Government imposes an indexed minimum wage w^{min}_t on firms, which set a lower bound to wage offers:

$$w^{min}_t = w^{min}_{t-1}\left(1 + \psi_1\frac{\Delta A_t}{A_{t-1}}\right), \tag{11}$$

A_t is the aggregate productivity, Δ is the time-difference operator, and $\psi_1 \in \mathbb{R}_+$, a parameter.

Each hiring firm makes a unique wage offer to the selected job applicants, if any. An employed worker accepts the best offer she receives if higher than current wage. An unemployed worker accepts the best offer if at least equal to the unemployment benefit. Employed workers quit the current firm when receiving a better offer, and this firm can replace this open position only in the next period, if needed.

The process described above allows for the possibility that the labour market does not clear. Firms may fail to fill all the open positions, and workers may not find a job even in presence of still unfilled positions. However, systematic discrepancies between vacancies and involuntary unemployment tend to be small.

3.3. Two-region model timeline and set-up

In each simulated period t, the following events take place in the K+S model:

1. Workers (employed and unemployed) update their skills;
2. Machines ordered in the previous period (if any) are delivered;
3. Capital-good firms perform R&D and signal their machines to consumption-good firms;
4. Consumption-good firms determine their desired production, investment and workforce;
5. Firms allocate cash-flows and (if needed) borrow from banks to operate and invest;
6. Firms send/receive machine-tool orders for the next period (if applicable);
7. Job-seeking workers send job applications to firms;
8. Wages are set and job vacancies are partly or totally filled;
9. Firms pay wages and government pays unemployment benefits;
10. Consumption-good market opens and market shares are allocated;
11. Firms and banks compute their profits, pay taxes and repay (part of) their debt;
12. Exit takes place, near-zero share and bankrupt firms leave the market;
13. Prospective entrants decide to enter according to market conditions;
14. Aggregate variables are computed and the cycle restarts.

We configured the model to compare the dynamics of two different regions characterised by the same initial conditions but distinct labour-market institutions, leading to different informality levels and security of employment degrees. Surely, we are not suggesting that such institutional differences are the single cause for the inter-regional divide, it may be not even the most important. However, from an analytical perspective, it seems an interesting hypothesis, even because it is not the most usual explanation in the literature, and for which we believe our model is adequate to test.

In order to characterise the two regions, we modelled them under alternative dynamics for job search, hiring, firing, and wage setting. In Table 1 we present the differences between the two. For all the remaining parts of the model, behavioural rules are exactly the same. In this way, we can isolate the role played by the labour market heterogeneity as a source of divergence between regions, as observed in the macro-dynamics variables, such as productivity, innovation, and investment, in particular, and on the technological and productive patterns, in general.

The North region labour market is modelled (i) to account for lower probabilities of workers being fired, allowing firms to fire only when at losses; (ii) wages insensitive to the business cycle, with full indexation to productivity; (iii) homogeneous wages in each firm; (iv) hiring and firing rules favouring workers with higher skills; (v) stronger worker-firm attachment, with employed workers less active on searching for better jobs. Longer tenure rates result into higher

Table 1
Differentiating characteristics of modelled regions.

	North	South
Labour-firing restrictions	under losses only	none
Wage indexation to productivity	full	partial
Differentiated firm-level wages	no	yes
Worker-hiring priority	higher skills	lower wages
Worker-firing priority	lower skills	higher wages
Worker job search intensity	low	high

skill level of the workforce. In this region, firm j updates existing workers to the same wage offered to new hires ($w_{j,t} = w^o_{j,t}$).

Conversely, the southern labour market is characterised by (i) higher probability of workers being fired due to the absence of firm restrictions, (ii) an increased sensitivity of wages to the business cycle due to only partial indexation of wages to productivity, (iii) heterogeneous wages among firm workers, (iv) rules targeting cheaper (more expensive) workers when hiring (firing), and (v) weaker worker-firm loyalty forcing stronger activity of worker on looking for better-pay jobs. Workers change wage only when moving to a new employer.

The K+S model is able to reproduce a large collection of stylised facts — statistical regularities —, at both micro- and aggregate-level (Dosi et al., 2010, 2017, 2018; Dosi, Pereira et al., 2020). Here, Fig. 2 presents a synthetic macro overview of the model results to validate the configurations proposed for the two regions.[3] It compares the performance of both labour markets in terms of unemployment and vacancy rate (panel a), average log real wage (panel b), worker-income inequality measured by the Gini index (panel c), and notional skill level of the workforce (panel d). The labour market results deeply differ in the two regions, as expected, and are in line with the set-up proposed in Table 1.

4. Sources of divergence

In the following we present a series of macro-level statistics focusing on innovation and investment variables, with the aim of capturing the extent to which differences in the two regional labour markets impact the model dynamics. Fig. 3 compares some key simulation results for the two regions, providing strong support to the hypothesis of "percolation" of asymmetries in the labour institutions to most domains of the regional economies. The main advantage of a theoretical model, as we keep all other possibles "sources" of divergence disabled, is that the gaps observed in the inter-regional comparison must be casually connected to the labour-market institutional asymmetries as the root cause.

The wage share, or functional income distribution (Fig. 3 panel a), shows a much higher instability, and frequently a lower level in the South.[4] Similarly, the R&D expenditure of firms (panel b) is also substantially lower in the long-run, leading to an increasing technological gap

[3] All time plots present the average values from 50 Monte Carlo runs for 500 time steps. The initial 100-period model warm-up is not shown.

[4] The surge on the wage share in the South in the last 100 periods is due to the gradual impoverishment of its economy, with the government incurring in large deficits and growing debt to sustain the payment of unemployment subsidies. Wage shares larger than one in this plot mean that aggregate profits are lower than the total unemployment benefits paid.

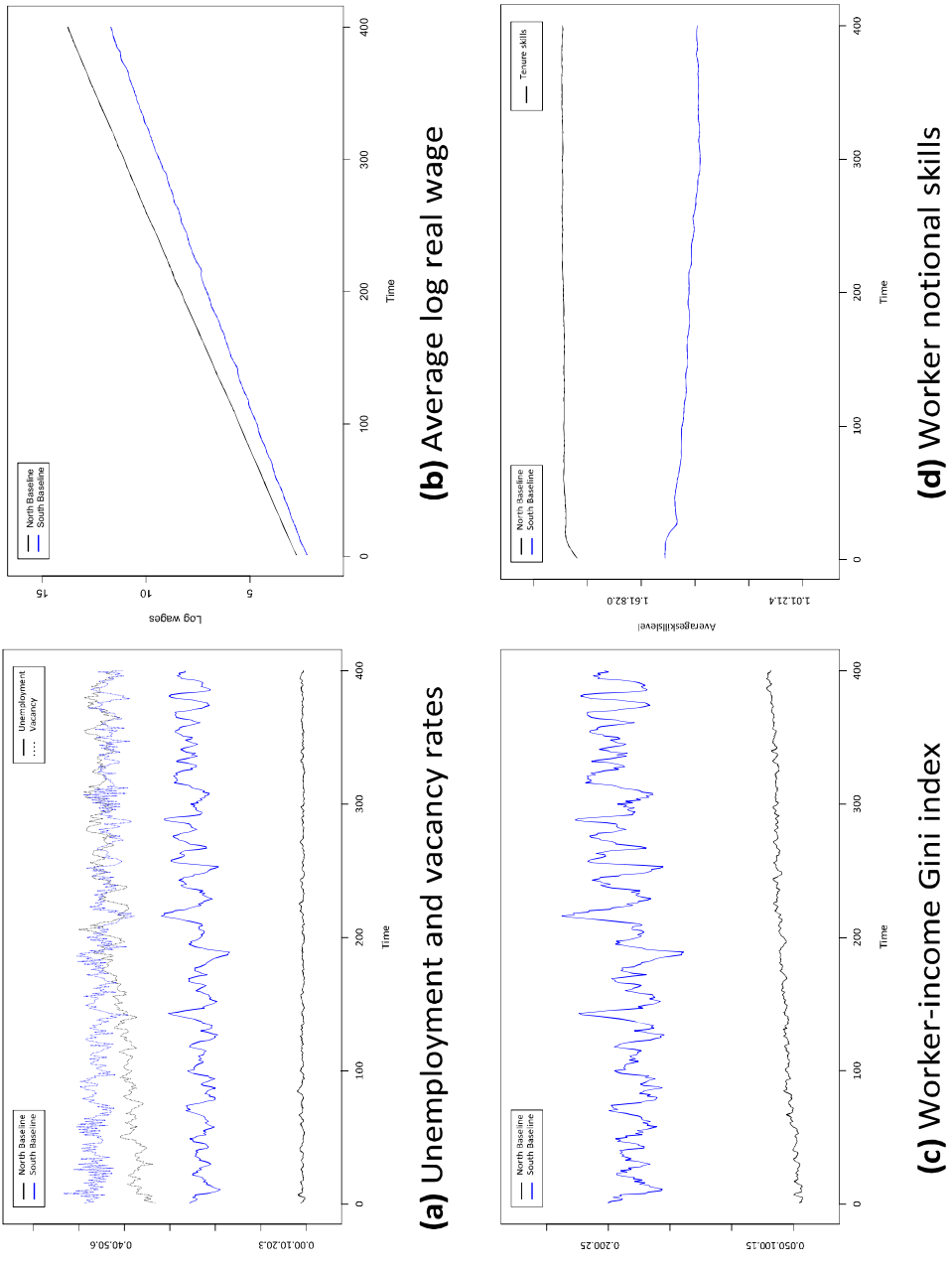

Figure 2. Comparison of regional labour markets (see note 3).

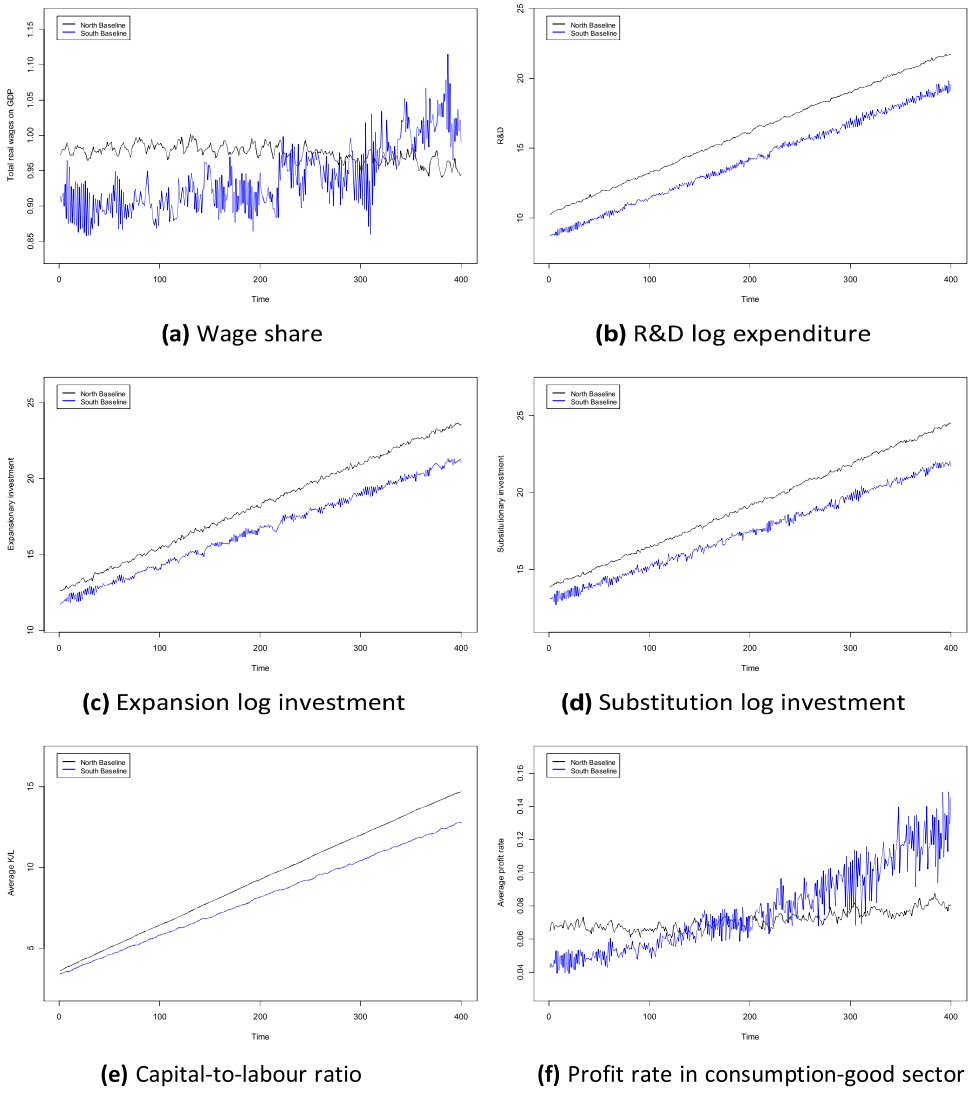

Figure 3. Divergence patterns between regions (see note 3).

due to the cumulative nature of research. The lower innovative activities in the upstream (capital-good) sector of the southern region is driven by the lower demand of machines deriving from the downstream (consumption-good) sector, whose investment also strongly diverges (panels c, d) both in terms of capacity expansion and old machine substitution. Recall that investment in capacity expansion is driven by higher demand of final goods. Considering the lower aggregate demand due to lower wages and wage share, investments in new capital goods are constrained because of the weak expected demand. Lower investment causes a contraction in the production of new machines, therefore reducing the effort in innovative R&D activities. Such results represent a first-order set of asymmetries deriving from the different organisation

Table 2
Performance comparison between regions (see note 5).

	North	South	
		S/N ratio	*p-value*
GDP growth rate	0.027	0.853	0.000
Productivity growth rate	0.027	0.851	0.000
Innovation success rate	0.288	0.809	0.009
Imitation success rate	0.309	0.843	0.000
Expansion log investment	20.58	0.784	0.000
Substitution log investment	21.51	0.809	0.000
Capital-to-labour ratio	11.89	0.865	0.000
Profit rate (downstream)	0.070	1.291	0.003

of the labour markets across regions. Indeed, negative feedback loops propagate from the labour market to the investment and innovative activities. Yet, notice that all those trends are pure (emergent properties), as regions started equal and everything except the labour market operates exactly the same in both.

Is it only the demand of new investment goods that lags behind in the South region, or final-good dynamics is affected as well? Fig. 3 shows how the slower pace of innovations also reduces the stimulus for machine-substitution investment (panel d), that is firms' interest to renew the capital stock, to produce more efficiently, given the small advantage of newer vintages of capital. Such lower level in both forms of investment results into a slower increase on the aggregate capital-to-labour (K/L) ratio (panel e), a usual proxy for mechanisation. What does it happen to the profit rate (panel f)? It shows an increasing average gross profit margin of southern downstream firms, indicating that investment in productive assets is not constrained by financial reasons, but because firms have no economic incentives to invest. Therefore, an *in-direct* rent-seeking-like mechanism wherein firms mainly rely on labour cost reduction, low worker skills, inferior product quality, slow innovation, and weak capital accumulation effort neatly emerges in the South region.

Table 2 provides a synthetic performance comparison between North and South.[5] All indicators related to positive aggregate performance, from GDP and labour productivity growth to both expansion/substitution investment are significantly worse in the South, substantiating the emergence of a falling behind pattern with respect to the North. This is evidenced from both the magnitude of the differences (the "S/N ratio") and the associated statistic significance (most well under the 1% level).

5. Policy strategies for the North-South convergence

Once ascertained the role of different labour-market institutions on the North-South divergence, we now move to identify possible policy strategies that may favour the convergence

[5] In all comparison tables, values are derived from averages of 50 MC runs in the last 200 simulated time steps. South-to-North region ratios are used to compare the relative difference between regions and are computed as the division of South MC averages by the North ones (the ratio is 1 if regions perform equally). The statistical significance *p*-value of the difference between regions is evaluated by a two-means *t*-test, H_0 being no difference between regions.

Table 3
Performance comparison between regions: Investment policy (see note 5).

	North	South (b = 3)		South (b = 9)		South (b = 12)	
		S/N ratio	*p-value*	*S/N ratio*	*p-value*	*S/N ratio*	*p-value*
GDP growth rate	0.027	0.853	0.000	0.912	0.000	0.931	0.001
Productivity growth rate	0.027	0.851	0.000	0.930	0.000	0.942	0.000
Innovation success rate	0.288	0.809	0.009	0.889	0.000	0.904	0.000
Imitation success rate	0.309	0.843	0.000	0.910	0.000	0.925	0.000

process. To this purpose, we comparatively assess the role of three convergence policies, which are affiliated or (i) to the institutional approach (the first two), operating via non-market mechanisms, or (ii) to the market-based stream (the last one), acting via a price mechanism, namely:

1. **Investment policy**, aimed at fostering faster substitution of machine vintages by consumption-good firms, and the acquisition of new machines from capital-good firms, governed in the model by parameter b in Eq. (3), which sets the expected maximum payback period of substitution investment;
2. **Learning policy**, targeted on increasing the workers' skills by means of on-the-job training, as defined by parameter τ_T in Eq. (5), which defines worker-skill accumulation while employed;
3. **Wage-indexation policy**, devising an increase on the elasticity of wage to firm-level productivity growth rates, driven by parameters ψ_2 and ψ_4 in Eq. (10), which establish the relative importance of the overall and own-firm productivity dynamics when defining wages.

Given the abstract nature of a theoretical model, these experiments represent stylised policies. It is not our objective to enter into the *necessary* details on how to achieve, in reality, the institutional and market changes represented by the proposed set of alternative parameter values. The idea is to, firstly, understand the *channels* through which policies can be more effective. Connecting the identified promising channels into concrete policy mixes is an important next endeavour, but clearly beyond the scope of this paper.

We start by presenting the results of the investment policy. We increase the parameter b governing the *economic* obsolescence of machines: a higher value enables firms to accept a longer period to recover the investment required for the substitution of the existing machines. Newer vintages of machines imply an increased productivity in manufacturing goods, as new machines embed more efficient technologies. Consistently, Table 3, presenting three alternative values for parameter b, shows that fostering substitution of old machines turns out to be highly effective in stimulating the convergence. According to all the metrics under consideration, namely GDP and productivity growth rates, innovation and imitation success rates[6] are significantly higher as the value of b increases. All results are statistically significant at 1% level or better.

[6] The innovation or imitation success rate is calculated as the share of capital-good firms successfully innovating or imitating in the R&D process, as described in Section 3.

The experiment results indicate that policies fostering more dynamic investment patterns in the South tend to stimulate the convergence process between regions. On this line, many contributions in the literature have highlighted the role of investment policies aimed at favouring the adoption of new technologies on the convergence process between northern and southern regions in Italy (Atzeni & Carboni, 2008).

From an evolutionary perspective, the upgrading of firms' machinery (i.e., embodied technical change) is indeed pivotal to maintain a highly dynamic technological profile of firms and to increase, in turn, the probability of catching-up for lagging-behind countries or regions (Dosi et al., 2009). In support of our results, a recent empirical contribution (Fiori & Scoccianti, 2021) also highlighted the negative role exerted by the poor dynamics of machine renewal among Italian firms on the aggregate productivity performance. Although focusing on the aftermath of the financial crisis (2011-12), the empirical results confirm the positive impact of more dynamic capital substitution activities, at the firm-level, on aggregate productivity.[7]

The second experiment studies the effect of a worker-oriented learning policy mapped by a gradual increase in the parameter τ_T governing workers' skills accumulation pace. Differently from the behaviour of the previous experiment, Table 4 shows a non-monotonic effect of an increase of τ_T. While a 1 p.p. increment of the parameter (from 0.01, the baseline, to 0.02) is ineffective in fostering convergence significantly, a 4 p.p. increase (to $\tau_T = 0.05$) is actually self-defeating for the aggregate dynamics. All results are statistically significant at 1% level or better.

Such unexpected experimental results derive from the increased concentration of few highly productive firms coexisting with a large fringe of low productivity ones. On-the-job training is more effective for firms producing and hiring more, increasing the skewness of the firm-size distribution because of a self-reinforcing process. In addition, higher learning rates are associated with increased overall profit rate, due to the diffusion of skilled workers even to laggard firms, reduced wage share, and, consequently, higher unemployment, more inequality, and a tiny fraction of elite firms dominating the downstream market.

The independent analysis of the first two policy experiments, rooted on the institutional approach, sheds light on the relevance of coordinating policies. As shown, a worker-training policy *per se* is likely insufficient for convergence. More probably, it can be combined with policies that foster the mechanisation of work, like the one proposed in our first experiment.[8] An investment policy aimed at strengthening the technological profile of less developed areas via more dynamic capital upgrade processes should be matched by labour-oriented policy interventions favouring the accumulation of workers skills (required by new machines) and firms' productive and organisational capabilities, or, ultimately, their dynamic interaction with more complex technological environments (Dosi et al., 2009; Freeman, 2002; Lundvall, 1992).

On this ground, on reference to a case of effective convergence, Boltho et al. (2018) highlight how the quite advanced capability endowment of the former East German Länder crucially contributed to the convergence process after the unification in 1989. At the opposite end, the lack of a proper set of techno-organisational capabilities in the South of Italy is one of the actual causes maintaining the gap with the North (Costa et al., 2021; Sbardella et al., 2021).

[7] A necessary qualification: the cited contribution addresses the effect of capital vintages' age on total factor productivity (TFP), represented by a standard neoclassical production function, while hereby we study the effects on total labour productivity, by adopting an evolutionary perspective to technical change and firm organisation.

[8] Indeed, the combination of experiments 1 and 2 in the K+S model, that is, the simultaneous increase of parameters b and τ_T, shows a slightly increased potential with regard to the separated experiments.

Table 4
Performance comparison between regions: Learning policy (see note 5).

	North	South (τ_T = 0.01)		South (τ_T = 0.02)		South (τ_T = 0.05)	
		S/N ratio	*p-value*	*S/N ratio*	*p-value*	*S/N ratio*	*p-value*
GDP growth rate	0.027	0.853	0.000	0.852	0.000	0.668	0.000
Productivity growth rate	0.027	0.851	0.000	0.869	0.000	0.678	0.000
Innovation success rate	0.288	0.809	0.009	0.818	0.000	0.717	0.000
Imitation success rate	0.309	0.843	0.000	0.847	0.000	0.740	0.000

Table 5
Performance comparison between regions: Wage-indexation policy (see note 5).

	North	South (ψ_4 = 0.5)		South (ψ_4 = 0.75)		South (ψ_4 = 1.0)	
		S/N ratio	*p-value*	*S/N ratio*	*p-value*	*S/N ratio*	*p-value*
GDP growth rate	0.027	0.853	0.000	0.831	0.000	0.801	0.000
Productivity growth rate	0.027	0.851	0.000	0.829	0.000	0.813	0.000
Innovation success rate	0.288	0.809	0.009	0.830	0.000	0.844	0.000
Imitation success rate	0.309	0.843	0.000	0.836	0.000	0.841	0.000

Therefore, rather than alternatives, labour and machine upgrading are complementary policies very likely effective in bolstering convergence. Moreover, from a policy perspective, Pistoresi et al. (2017) recently highlighted the crucial role that government programmes aimed at the improvement of education may exert in Italy, giving impulse towards a virtuous national innovation system.

The third experiment presents instead a market-based policy. We intend to study the effect of a higher importance of firm-level productivity growth (instead of overall regional productivity advances) on the wage setting process of firms. We increase the value of the parameter ψ_4 vis-à-vis ψ_2, governing the wage increase with respect to firm-level and aggregate productivity, respectively (preserving $\psi_2 + \psi_4 = 1$). The underlying idea is that a higher indexation of wages to *local* productivity growth, making wages more sensitive to firm-level dynamics, will reward more those workers employed in high-productivity firms, and conversely. The net effect would result in more flexible and sensitive wage adjustments to local changes, therefore making the labour market more efficient.

Table 5 compares three alternative values for parameter ψ_4 — and, consequently, to ψ_2 — ranging from medium (the baseline) to full indexation at the firm-level. The results show that this market-based policy is ineffective in fostering the convergence process, more likely increasing it. The growth rates slightly reduce as we increase the sensitivity to local productivity, despite the small increase of the R&D successes. As before, all results are statistically significant at 1% level or better.

The experimental results are quite enlightening for the policy debate on the Italian North-South divide. On the one hand, data suggests that investment policies, here modelled by the substitution of old vintages of machines, are highly effective in fostering convergence. On the other hand, a pro-market local wage setting, implemented by increasing the weight of firm-level

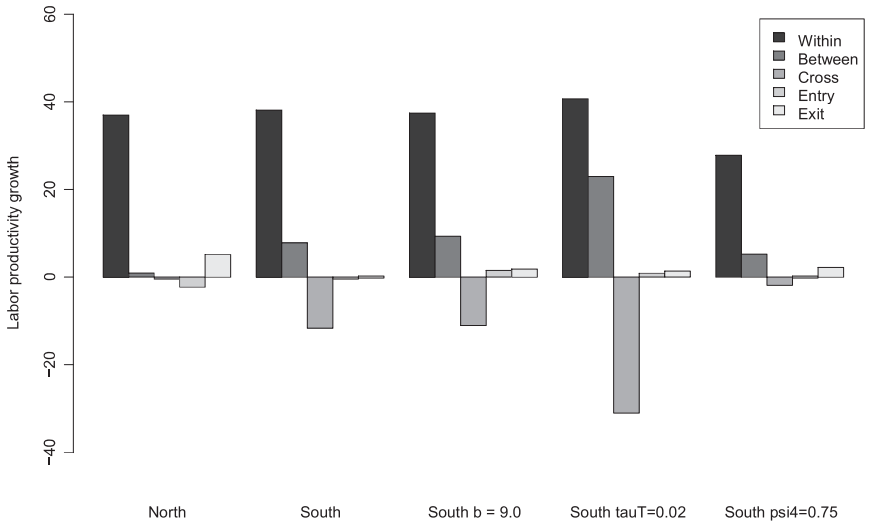

Figure 4. Effects of alternative policies: labour productivity decomposition.

Table 6
Decomposition of log-normalised labour productivity growth across policies.

	Total	Within	Between	Cross	Entry	Exit
North (baseline)	40.85	37.03	0.93	0.02	− 2.28	5.15
	(0.77)	(0.71)	(0.16)	(0.13)	(0.15)	(0.19)
South (baseline)	34.62	38.15	7.85	− 11.65	0.03	0.25
	(0.60)	(0.62)	(0.14)	(0.21)	(0.03)	(0.03)
South $b = 9$ (investment policy)	39.2	37.48	9.34	− 11.04	1.55	1.88
	(0.64)	(1.15)	(0.25)	(0.49)	(0.46)	(0.38)
South $\tau_T = 0.02$ (learning policy)	34.97	40.68	23.01	− 31.00	0.90	1.38
	(1.06)	(0.92)	(0.50)	(1.00)	(0.32)	(0.22)
South $\psi_4 = 0.75$ (wage-indexation policy)	33.70	27.82	5.25	− 1.85	0.26	2.21
	(1.75)	(1.67)	(0.23)	(0.11)	(0.30)	(0.07)

Results computed over a rolling window of 8 periods from averages of 50 MC runs in the last 200 simulated time steps. Monte Carlo standard errors in parenthesis.

productivity on wage indexation, is actually ineffective in terms of catching-up. In the middle, it seems that other possibly relevant strategies, like the worker-training push tested here, may only be relevant when combined with other actions.

On the limits of the modelled pro-market policy, we can parallel the effects of the local wage-indexation policy to the so-called "*gabbie salariali*" (wage traps), a policy scheme used in Italy during the 1960's and the 1970's. It has dramatically exacerbated the North-South gap, by leading to low-productivity strategies at the firm level, and a low-technology sectoral composition in the Mezzogiorno (Graziani, 1989, 1993; Svimez, 2019). The adoption of this scheme has been recently re-proposed in the debate by means of policy proposals calling for wage flexibilization and local wage-productivity indexation to enhance the convergence process

(Boeri et al., 2021). However, our results do not give support to such proposals, which more likely will turn out to be ineffective in convergence terms, if not increasing regional disparities.

Finally, in order to investigate how alternative policy strategies affect labour productivity growth, we analyse its components. Following Foster et al. (2001), a shift-and-share decomposition is performed, aimed at distinguishing the individual contributions to the labour productivity growth in our simulated consumption-good sector. In particular, the decomposition allows identifying the adjustments taking place within the sector, whether due to firm-level learning or reallocation of labour that contributed the most to the observed pattern of productivity growth.

The decomposition components are: (i) *within-firm*, the part of productivity growth generated at firm-level, the only true learning component; (ii) *between-firm*, the effect of reallocating the employment share between firms with heterogeneous productivity; (iii) *cross-firm*, the interaction component deriving from the two previous ones, all three due to the dynamics of incumbent firms; (iv) *firm-entry*, due to the contribution to labour reallocation of firms entering the market; and (v) *firm-exit*, the similar effect from exiting firms. Formally, it is computed allocating the micro-data according to:

$$\begin{aligned}\Delta \log A_t \;=\; & \underbrace{\overbrace{\sum_j f_{j,t-h}\,\Delta \log A_{j,t}}^{WITHIN} + \overbrace{\sum_j \Delta f_{j,t}\,(\log A_{j,t-h} - \log A_{t-h})}^{BETWEEN} + \overbrace{\sum_j \Delta \log A_{j,t}\,\Delta f_{j,t}}^{CROSS}}_{INCUMBENTS} \\ & + \overbrace{\sum_j f_{j,t}\,(\log A_{j,t} - \log A_{t-h})}^{ENTRY} \\ & - \overbrace{\sum_j f_{j,t-h}\,(\log A_{j,t-h} - \log A_{t-h})}^{EXIT}\end{aligned} \tag{12}$$

where $f_{j,t}$ and $A_{j,t}$ are the employment share and the labour log productivity of firm j, and $\log A_t$ is the sectoral weighted-average log productivity in period t.[9] Fig. 4 synthesizes and Table 6 details the decomposition results. The analysis is performed on the baseline trajectories of both regions plus the three experiments. We select an intermediary parameter setting to represent each experiment: $b = 9$ for the investment policy, $\tau_T = 0.02$ in the case of the learning policy, and $\psi_4 = 0.75$ for the wage-indexation one.

The investment policy fosters productivity growth vis-à-vis the baseline South primarily via the labour reallocation due to increased firms' entry and exit, both positively contributing, without touching much the other components, producing a significant net contribution. The learning policy fosters higher productivity growth via both the within- and between-firm effects, as expected, but simultaneously induces a significant negative cross-firm effect. This is because of opposite co-movements between changes in labour productivity and in employment shares hinting at labour-shedding processing occurring in high-productivity firms, producing only a marginal positive net effect. Finally, the wage-indexation policy reduces both the positive within- and between-firm components, despite moderating the negative cross-firm effect, and

[9] The decomposition is computed over a rolling window of fixed length (8 periods), which adds an extra term for the unexplained difference between the total and the sum of the decomposition components, not shown here.

still slightly increases the positive contribution of firm-exit vis-à-vis the South baseline. The net effect is negative. These results seem to confirm the analysis put forward above, now on a quantitative perspective.

6. Conclusions

To what extent the Italian North-South divide might be mitigated by policies for convergence? Comparing market versus non-market based approaches, which may be more effective? This paper addresses these questions by means of an agent-based theoretical model able to firstly account for patterns of structural divergence, and then employed to test and compare alternative policy mechanisms, removing the uncertainty on causality which usually plagues empirical analyses. The model, encompassing two regions characterised by the same productive and innovation structure, but differentiated in the labour market organisation, is able to reproduce the persistent divergence in most outcome variables. Therefore, we initially provide evidence of the negative feedback loops going from informal and weak labour markets to both innovation and production dynamics. Even if other gap-enhancing drivers may be present in reality, the model convincingly shows how labour-market institutional asymmetries should be considered a potentially serious source of divergence, in a set-up where causality is fully controlled.

Once the main sources of divergence in the model are identified, we analyse the effects of three different experiments representing stylised single-channel policies, namely, an investment policy fostering machine-capital upgrading, a learning policy aimed at increasing worker skills and productivity, and a local wage-indexation policy increasing the importance of firm-level productivity growth on wage setting. According to our results, the investment policy turns out to be the most effective in reducing the regional gap. When decomposing the labour productivity growth using shift-and-share analysis, we find that this effect is mainly due to a positive firm entry and exit dynamics driving the overall increase. Next, the learning policy seems ineffective if adopted in isolation, being possibly an interesting complement to an investment-push strategy, due to the complementary stimulus for the within-firm productivity growth. Conversely, the wage-indexation policy fails in fostering convergence, maybe even increasing divergence, mainly due to the weaker push to the within-firm component of productivity advancement. From those results, and considering we are addressing only one of the possible sources of the inter-regional divide, it seems that a sensible policy mix should include an investment component coupled with a training one.

The agent-based modelling methodology looks promising in understanding which directions of policy interventions might be more adequate to promote the economic convergence between leading and lagging regions or countries, as it can be easily extended beyond the specific Italian case to a broader domain on the convergence of developing economies. With respect to the extant agent-based literature, our contribution specifically addresses the study of alternative policy schemes, and their net impact in terms of both macroeconomic attributes and industrial dynamics. However, several improvements could be incorporated into our analytical setting. Limitations include the absence of the rise and fall of new technologies and sectors (Dosi, Pereira et al., 2022), for a recent ABM advancement), potentially affected by policy interventions, the absence of trade between regions, and the missing role of education in the

catching-up process. Indeed, education, trade and structural change are at the core of any theory of economic development and the ensuing patterns of convergence/divergence (Meier & Stiglitz, 2001). Therefore, addressing such specific limitations should remain in our research agenda.

In terms of policy implications, our paper seems quite telling about the urgent need of developing policies able to foster convergence while simultaneously addressing the climate change transition challenges. Configured as such, they may become coherent strategies able to tackle the *triple crisis* (social, economic, and ecological). Indeed, selective industrial policies to reconvert the so-called *cathedrals in the desert*, or left-behind places in general (Leyshon, 2021) — the places that do not matter (Rodríguez-Pose, 2018) —, might constitute part of a larger strategy able to tackle, at the same time, not only the productive reconversion, but also the social and ecological upgrading of such regions. The South of Italy is plenty of cases like outdated steel plants, petrochemical complexes, or mining sites connected with strong environmental pollution and socio-economic backwardness. Targeted industrial policies, in combination with the Next Generation EU plan, should exactly start from places like those.

Appendix

Tables A.1, A.2

Table A.1
Initial-condition values (baseline configuration).

Symbol	Description	Value
μ_0^2	Initial mark-up in consumption-good sector	0.200
w_0^{min}	Initial minimum wage and social benefit floor	0.500
K_0	Initial capital stock in consumer-good sector	800
L_0^S	Number of workers	2.510^5
Λ_0	Prudential limit on debt (initial fixed floor)	20,000
B	Number of banks	10
NW_0^b	Initial net wealth of banking sector	1.010^6
Sav_0	Initial consumer unfilled-demand savings	1.110^6
(Deb_0^1, Deb_0^2)	Debt-to-equity ratio of capital/consumption-good firms	(1,1)
(F_0^1, F_0^2)	Initial number of capital/consumption-good firms	(20,200)
(NW_0^1, NW_0^2)	Initial net wealth capital/consumption-good sector	(10,000,5000)

Table A.2
Parameter values (baseline configuration).

Symbol	Description	Value
Policy and credit market		
ϕ	Unemployment subsidy rate on average wage	0.200
tr	Tax rate	0.100
r	Prime interest rate	0.010
r_D	Interest rate on bank deposits	0.000
μ_{deb}	Mark-up of interest on debt over prime rate	0.000
μ_{res}	Mark-up of interest on reserve to prime rate	1.000
Λ	Prudential limit on debt (sales multiple)	3
Labour market		
δ	Labour force growth rate (per country)	0.000
ϵ	Minimum desired wage increase rate	0.020
τ_T	Skills accumulation rate on tenure	0.010
τ_U	Skills deterioration rate on unemployment	0.010
T_r	Number of periods before retirement (work life)	120
T_s	Number of wage memory periods	N:0 / S:4
ω	Number of firms to send applications (employed)	N:2 / S:5
ω_u	Number of firms to send applications (unempl.)	10
ψ_2	Aggregate productivity pass through	0.500
ψ_4	Firm-level productivity pass through	0.500
ψ_6	Share of firm free cash flow paid as bonus	0.200
Technology		
η	Maximum machine-tools useful life	19
ν	R&D investment propensity over sales	0.040
ξ	Share of R&D expenditure in imitation	0.500
b	Payback period for machine replacement	9
m_1	Labour scale in capital-good sector	0.1
m_2	Machine-tool unit production capacity	40
(α_1, β_1)	Beta distribution parameters (innovation process)	(3,3)
(α_2, β_2)	Beta distribution parameters (entrant productivity)	(2,4)
(ζ_1, ζ_2)	Search capabilities for innovation/imitation	(0.300,0.300)
$[\underline{x}_1, \bar{x}_1]$	Beta distribution support (innovation process)	[− 0.150,0.150]
Industrial dynamics		
γ	Share of new customers for capital-good firm	0.500
$\imath$	Desired inventories share	0.100
μ_1	Mark-up in capital-good sector	0.100
o	Weight of market conditions for entry decision	0.500
χ	Replicator dynamics coefficient (compet. intensity)	1.000
υ	Mark-up adjustment coefficient	0.040
ω_1	Competitiveness weight for price	1.000
ω_2	Competitiveness weight for unfilled demand	1.000
ω_3	Competitiveness weight for quality	1.000
u	Planned utilisation by consumption-good entrant	0.750
f^2_{min}	Min share to stay in consumption-good sector	10^{-5}
n_1	Periods without orders to stay in capital-good sector	8
x_5	Max technical advantage of capital-good entrant	0.300
$[\Phi_1, \Phi_2]$	Min/max capital ratio for consumer-good entrant	[0.100,0.900]
$[\Phi_3, \Phi_4]$	Min/max net wealth ratio for capital-good entrant	[0.100,0.900]
$[\underline{x}^1_2, \bar{x}^1_2]$	Entry distribution support for capital-good firm	[− 0.150,0.150]
$[\underline{x}^2_2, \bar{x}^2_2]$	Entry distribution support for consumer-good firm	[− 0.150,0.150]
$[F^1_{min}, F^1_{max}]$	Min/max number of capital-good firms	[1,100]

(*continued on next page*)

Table A.2 (*continued*)

Symbol	Description	Value
$[F^2_{min}, F^2_{max}]$	Min/max number of consumer-good firms	[1,400]

N:x / S:y indicate different values for (N)orth and (S)outh regions.

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