OECD-EC high-level workshop series Productivity Policy for Places

Innovation-productivity paradox

Implications for regional policy

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The notion of innovation-productivity paradox refers to the co-existence of exciting new technological innovations (e.g., artificial intelligence, digitalisation, machine learning and robotics) and declining productivity rates in the 21st-century OECD economies. This paper explores the regional dimension of the paradox in question. It aims to distil a set of theory-informed policy implications grounded in key ‘areas of agreement’ among three relevant kinds of research: economic research on the global productivity slowdown, innovation paradoxes research, and regional innovation studies. Overall, the paper underscores that several critical causal factors of the global productivity slowdown are very likely to be operative at the subnational level, rather than solely at the level of firms and nations; hence, the regional scale constitutes a fertile ground to design and implement place-based policies that could boost inclusive productivity growth in the COVID-19-riddled OECD economies.

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DISCLAMER

This paper was prepared as a background document for an OECD-EC high-level expert workshop on "Productivity Policy for Places – Innovation-Productivity Paradox" held virtually on March 3 and 5. It sets a basis for reflection and discussion. The background paper should not be reported as representing the official views of the European Commission, the OECD or one of its member countries. The opinions expressed and arguments employed are those of the author(s).

ABOUT THE OECD-EC HIGH-LEVEL EXPERT WORKSHOP SERIES ON PRODUCTIVITY POLICY FOR PLACES

The workshop is a part of the five-part workshop series in the context of the OECD-EC project on "Productivity Policy for Places". The five workshops cover the following topics: (1) Innovation-Productivity Paradox; (2) Productivity in the Private Sector; (3) Public Sector Productivity; (4) Inclusive Productivity? and (5) Productivity and Resilience.

The outcome of the workshops supports the work of the OECD Regional Development Policy Committee and its mandate to promote the design and implementation of policies that are adapted to the relevant territorial scales or geographies, and that focus on the main factors that sustain the competitive advantages of regions and cities. The seminars also support the Directorate-General for Regional and Urban Policy (DG REGIO) of the European Commission. The financial contributions and support from DG REGIO are gratefully acknowledged.

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Introduction

Productivity – i.e., the ability of an economic agent (e.g., firm, industry, city, region, nation) to transform a given set of inputs into higher outputs – has long been regarded as one of the most important indicators of economic success in capitalist economies (Freeman and Louçã, 2001; OECD, 2018a; Grifell-Tatjé, Lovell and Sickles, 2018; McCann and Vorley, 2020). Despite being a narrow measure of social welfare, productivity is, nonetheless, an essential precondition for achieving and sustaining it over time. For instance, wage growth, rising income per capita and improvements in the public infrastructure depend in the long-term on productivity. As Paul Krugman (1994) put it: *"[p]roductivity isn't everything, but, in the long run, it is almost everything*" (p.13).

Since the late 1980s, the question of productivity has occupied a prominent place on the agenda of both social scientists and policy-makers across the world. Central in this regard is Robert Solow's famous phrase: "*You can see the computer age everywhere but in the productivity statistics*" (Solow, 1987). A rapidly growing number of studies have offered a fresh perspective on Solow's observation by showing that productivity growth[1] has, since the 1980s, gradually fallen by 50% in G7 countries (Erber, Fritsche and Harms, 2017; Martin et al., 2018). Other studies have extended this finding by illustrating that declining productivity rates represent a generic aspect of economic development in OECD economies (Andrews et al. 2016, Bergeaud et al. 2016, Dieppe 2020). In short, the productivity slowdown is no longer a particular issue of the US economy but a global economic phenomenon.

This development inevitably raises the scientific question of *causality,* i.e., what are the underlying causes of the global productivity slowdown? Various factors have been proposed as possible determinants of sluggish and declining productivity rates in the OECD economies. Ageing population, declining business dynamism, capital deepening, global financial crisis, increasing household debt, immigration, rising income inequality, methodological errors, technological innovation, and structural change (e.g., from manufacturing to services) have all been proposed as possible causal factors (Syverson, 2017; Crafts, 2018; Goldin et al., 2020). However, from all these possible causes, it is innovation – especially in the form of general-purpose technologies (GPTs) such as artificial intelligence, robots, and digital technologies – that is, increasingly, being regarded as the main culprit for weak productivity growth (Brynjolfsson and McAfee, 2014; Gordon, 2017; Crafts, 2018; Goldin et al., 2020; Ortega-Argiles and McCann, 2021).

On the one hand, the focus on innovation is reasonable: innovation is the main engine of long-term productivity, competitiveness and development in capitalist societies (Schumpeter, 1934; Nelson and Winter, 1982; Freeman and Louçã, 2001). Despite being risky, uncertain and failure-prone, innovation enhances the competitiveness, market power and survival of firms and sectors (Porter, 1990; Malerba, 2006; Dodgson, 2017). This, in turn, leads to significant productivity gains and improvements in the living

[1] Productivity can be measured by using different methods, indicators and statistical techniques (Del Gatto, Di Liberto and Petraglia, 2011; Balk, 2018; Tsvetkova et al., 2020). As Ortega-Argiles and McCann (2021) nicely put it, "there is no unique measure of productivity" (p.4). Two main approaches to productivity measurement are often used: single-factor productivity (e.g., labour productivity), and multifactor or total factor (e.g., production function) productivity. For an overview of both approaches, and their relevance to measuring the productivity of regions, firms and public organisations, see Ortega-Argiles and McCann (2021), Egger (2021) and Krawchenko (2021).

standards of the territorial units (e.g., nations, regions and cities) where innovation takes place (Acs and Varga, 2002; Pianta, 2005; OECD, 2009; Tsvetkova et al., 2020). On the other hand, however, it is quite puzzling that at a time when economic activity has been more innovation-intensive ('smart') than ever before, productivity growth has either slowed down or fallen significantly across the OECD countries (European Commission, 2010; OECD, 2018b; Martin et al., 2018). It is the latter aspect in the relationship between innovation and productivity that has been known as ***the innovation-productivity paradox***.

Despite being an increasingly popular object of research, the extant literature on the global productivity slowdown remains oblivious of a few stylised facts of research on both innovation and productivity. First, and despite the strong operation of the 'twin forces' of globalisation and digitalisation, innovation continues to exhibit a pronounced tendency towards geographical clustering and concentration in a few cities and regions (Morgan, 2004; OECD, 2009; Feldman and Kogler, 2010; Florida, Adler and Mellander, 2017; Fritsch and Wyrwich, 2021b). Second, the existence of striking and persistent productivity gaps among cities and regions within the same nation affirms, among other things, that the underlying causal factors of productivity growth, including productivity gaps, reside mainly at the subnational level rather than at the levels of firms and nations (Duranton, 2008; Combes et al., 2012; Martin et al., 2018; Tsvetkova et al., 2020). Given the above, thus, it is very likely that the innovation-productivity paradox has a strong, yet underexplored (in terms of both research and policy), subnational dimension.

This paper explores in a conceptual manner the regional dimension of the paradox in question. First, it identifies 'trading zones' – i.e., areas of agreement – among three kinds of relevant literature: the relevant literature on the ***global productivity slowdown*** from the field of economics; the literature on ***innovation paradoxes*** from the field of innovation studies; and the relevant literature on ***regional innovation*** from the field of economic geography. Second, the paper utilises the identified trading zones as the theoretical basis to develop a 'menu' of regional policy implications.

Overall, the discussion in this paper draws on three main policy-relevant observations and suggestions:

- The existing research on the global productivity slowdown has mainly considered possible causes at the macro and micro-levels with its primary research focus being on the US; hence, the findings of this line of research do not offer, at this stage, a sophisticated understanding of the regional causes of the productivity slowdown in the OECD member states;
- A synthesis of the relevant literature on productivity slowdown, innovation paradoxes research and regional innovation studies offers several interesting policy-relevant ideas and insights regarding the type of policy initiatives that could be implemented to improve regional productivity in different types of regions;
- Regional policy makers are advised to approach productivity issues in their jurisdiction with an evidence-based, place-sensitive rationale.

1 Innovation paradoxes: What are they? Do they matter? What causes them?

The concept of 'innovation paradox' encompasses a family of anomalous observations demonstrating that relatively high or outstanding investments in innovation lead to either insignificant or undesirable economic outcomes (Dosi, Llerena and Labini, 2006; Bitard, Edquist and Hommen, 2008; Fragkandreas, 2017). Innovation paradoxes are significant intellectual devices (Andriopoulos and Gotsi, 2017). Their significance lies in their contradictory nature and the implications that emanate from it.

Consider, for instance, the innovation-productivity paradox. The paradox in question captures the discrepancy between popular beliefs (e.g., theory) and practice (e.g., empirical observation). In terms of theory, it implies that innovation-growth theories (e.g., endogenous growth theory) may fail to capture what is going on in the economic system; thus, they need to be abandoned or reformulated. In terms of observation, the paradox in question suggests that the productivity potential of promising general-purpose technologies (GPTs) has been fully exploited (the *pessimistic view* – Gordon, 2017). At the same time, it implies that there might be significant bottlenecks (e.g., transitory technological incompatibilities and diffusion lags) that impair the ability of innovation to increase productivity in the OECD countries (the *optimistic view* – Brynjolfsson and McAfee, 2014a). While the pessimistic view leaves no room for policy action, the optimistic view sees in the innovation-productivity paradox an unexploited policy opportunity

Innovation paradoxes have a long intellectual history in the social sciences (see, for instance, Table 1). They can take various forms, while they occur at particular places, epochs and different levels (e.g., firm, sector, region, nation). A key stylised finding of research on innovation paradoxes is that multiple factors and forces determine the occurrence, including the resolution, of an innovation paradox (Bitard, Edquist and Hommen, 2008; Fragkandreas, 2017). To make sense of such a 'plurality of causes', this paper utilises a typology of innovation paradoxes research (Fragkandreas, 2017). Grounded in three decades of research on innovation paradoxes, the typology in question consists of the following four key explanatory categories[2]:

- ***Research base explanatory category***: the innovation-productivity paradox is caused by problems and inabilities in the (regional) research-science base;
- ***Economic base explanatory category***: the innovation-productivity paradox is the outcome of specific activities and inabilities of the (regional) economic system, particularly of regional firms, cluster and sectors;
- ***Innovation system explanatory category***: the innovation-productivity paradox is due to structural problems, inabilities, and inefficiencies in (regional) innovation systems; and

[2] As will be shown throughout this paper, each of these explanatory categories contains a set of explanations for the innovation-productivity paradox.

- ***Validity explanatory category***: 'there is no paradox'; it is all a matter of how one defines, theorises and measures the relationship between innovation and (regional) productivity.

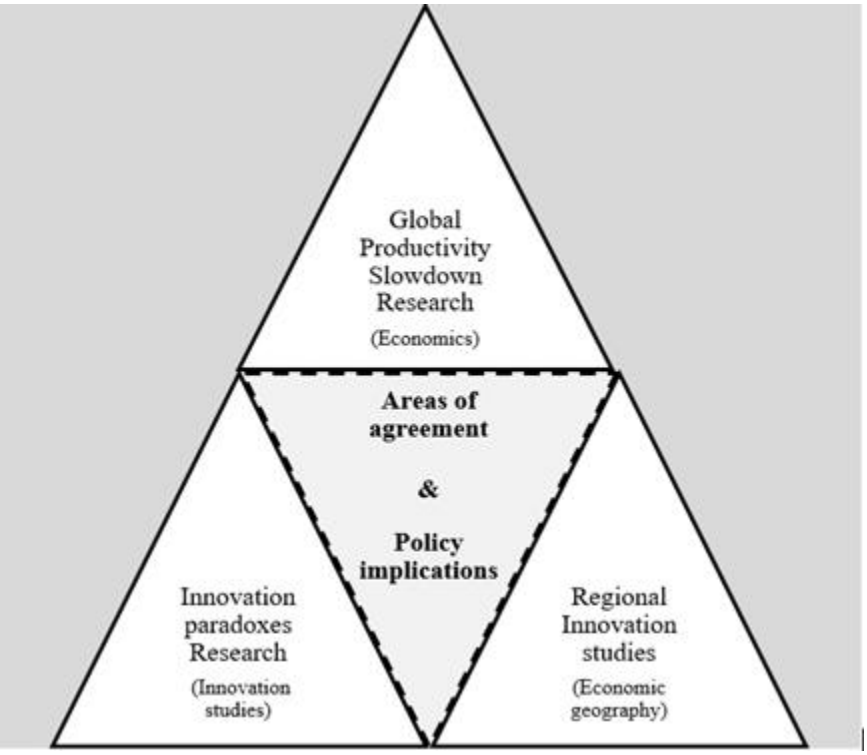
Table 1. List of innovation paradoxes

Paradox	Description	Source
Australian innovation paradox	Australia's poor performance in translating its relatively high innovation inputs into innovation outputs	Jackson et al. (2016, p.253)
Biotechnology innovation paradox	The survival and strength of the biotechnology sector is based on the innovative capability of biotech companies, but these become less innovation-intensive as they grow	Baker (2003)
Developing nations innovation paradox	While innovation is central to closing the gap between developed and developing countries, the latter do not invest enough in innovation	Cirera and Maloney (2017)
European paradox	The European paradox refers to the inability of the European Union to transform its scientific excellence into innovation, competitive advantage, wealth and employment	European Commission, (1995)
European regional paradox	The European regional paradox refers to the observation that some of the most innovation-intensive regions in Europe not only grow at a slower pace, but also have lower income per capita and lower employment than the national average under consideration	Fragkandreas (2013)
Fogel's (1964) innovation paradox	This paradox refers to the observation that the benefits of investing heavily in a generic purpose technology, such as the railway, did not have a significant pay-off for the US	Fogel (1964)
French innovation paradox	French SMEs dedicate a great deal of their resources to innovation (e.g., R&D investments), though this results in a weak performance in terms of innovation outputs	Liu and Laperche (2015)
Italian paradox	While Italy's R&D resources significantly lag behind those of other major economies, its output, in terms of scientific publications, is one of the most prolific in the world	De Martinis (2016)
Innovation-productivity paradox	The co-existence of exciting new radical technological innovations and declining productivity in OECD economies	Crafts (2018), Ortega-Argiles and McCann (2021)
Norwegian innovation paradox	The Norwegian innovation system combines high economic performance and innovative capability with relatively low investments in innovation inputs	Grønning, Moen and Olsen (2008)
Open innovation paradox	The open innovation paradox refers to the observation that firms seek simultaneously to share and protect knowledge when they form innovation collaborations and alliances with other firms and organisations	Bogers (2011)
Periphery innovation paradox	Despite the growing significance of innovation policy in both Latin American and the Central-Eastern European economies, the latter lack the relevant policy capacity and effectiveness to take advantage of innovation	Kattel and Primi (2012)
Regional innovation systems paradox	This paradox refers to the observation that many regional innovation systems produce little innovation and few jobs	Christopherson and Clark (2007b, pp.107–123)
Scale effects paradox (also known as Jones critique)	The scale effects paradox refers to the observation that while the number of scientists engaged in R&D in advanced countries has grown dramatically over the last 40 years, the growth rates of advanced countries have either exhibited a constant mean or even declined on average	Jones (1995)
SMEs innovation paradox	SMEs typically lack economies of scale and scope, as well as financial assets, while they have weaker competencies and absorptive capacity. Nevertheless, many SME invest heavily in high-risk innovation-related activities, such as R&D	Ortega-Argilés, Vivarelli and Voigt (2009)
Solow paradox	"You can see the computer age everywhere but in the productivity statistics"	Triplett (1999)
Southern European innovation Paradox	Despite the weakness of their institutional systems and the defensive policies developed by governments, some of the companies in Southern European countries (e.g., Italy, Spain and Portugal) have, nevertheless, been able to innovate even during the hardest years of the sovereign European debt crisis and the recession that came after it	Donatiello and Ramella (2017)
Strategy innovation paradox	While the competitive advantage and survival of firms rely on innovation, business executives pay little attention to innovation	Haour (2004)
Swedish paradox	A generalised version of the Swedish paradox refers to the observation that outstanding investments in R&D and innovation-related activities generate little economic return in terms of new products, competitiveness, growth and employment	Edquist and McKelvey (1998), Bitard, Edquist and Hommen, (2008)

Source: Author's elaboration based on Fragkandreas (2017).

The remainder of this paper utilises the four above explanatory categories as the point of reference in organising and navigating the discussion in this paper. The latter proceeds by means of ***theoretical triangulation***, namely by identifying 'trading zones' and 'areas of agreement' among three research streams (Figure 1): research on the ***global productivity slowdown*** from the field of economics; ***innovation paradoxes*** research from the field of innovation studies; and ***regional innovation studies*** from the field of economic geography. Conjoining key insights from these three strands of literature is of significance to our understanding of the regional aspects of the innovation-productivity paradox. The underlying aim of theoretical triangulation in this paper is to lay a common theoretical ground, upon which to erect a set of theory-informed regional policy implications.

Figure 1. Theoretical triangulation and policy implications



Source: Author's elaboration.

2 Regional research base: Key insights and policy implications

This section examines a set of explanations attributing the underlying causes of the innovation-productivity paradox in the early stages of the innovation process in general and in the regional research and development (R&D) system in particular. The discussion leads to the following four regional policy implications:

- Evolutionary-inspired initiatives (e.g., exaptation-orientated research projects) could be used to stimulate regional productivity in all types of regions;
- Enhancing the 'entrepreneurial ecosystem' potential of universities could increase regional productivity by, for instance, facilitating the emergence and diffusion of more efficient and resilient business models in a region;
- Removing obstacles that impede knowledge transfer among scientific organisations and firms could increase regional productivity by, for instance, reducing diffusion lags in the innovation process;
- Maintaining high rates of regional productivity growth may, among other things, require higher investments in R&D activities.

Productivity slowdown research

The emergence of endogenous growth theory in the 1990s did, among other things, reinvigorate the linear view on innovation (Kline, and Rosenberg, 1986; Romer, 1990; Grossman and Helpman, 1994; Lundvall et al., 2002). According to this view, R&D activities constitute the primary sources of innovation in modern-day economies (Kline and Rosenberg, 1986; Balconi, Brusoni and Orsenigo, 2010). In this regard, it is not surprising that several economic studies link the productivity slowdown with the efficiency of R&D activities. C.Jones (1995), for instance, argues that decreasing returns to scale are central to the relationship between R&D and growth in modern-day economies. More recent research attributes the existence of weak scale effects to what Arthur (2007) calls the *structure of invention*. B. Jones (2009), for instance, shows that idea-generation has become more complex over time, requiring intensive use of research, knowledge and team collaboration; a finding that he calls the 'knowledge burden mechanism'. Similarly, Bloom et al. (2020) find that the knowledge burden mechanism leads to declining productivity growth in the US. To illustrate their finding, these authors refer to the semi-conductor industry: R&D activities in the 21st century semi-conductor industry require 18 times more input to achieve the output seen in the 1970s.

Overall, this line of research implies that the more technologically advanced and complex the innovation process becomes, the less efficient R&D activities tend to be. In this regard, a key challenge which research-intensive regions may currently be facing is how to 'run to stand still', namely how to maintain,

rather than increase, the existing rates of regional productivity growth. In this context, higher R&D investments could be seen as a 'necessary evil' rather than as the primary cause of declining regional productivity rates.

Innovation paradoxes research

Since the 1990s, the notion of the European paradox[3] has been an object of extensive research and policy discussions, especially in Europe (Granberg and Jacobsson, 2006; Dosi, Llerena and Labini, 2006; Jacobsson, Lindholm-Dahlstrand and Elg, 2013; Ortega-Argilés, Piva and Vivarelli, 2014; Fragkandreas, 2017). Early research on the European paradox shows that the European scientific system suffers from: (1) *weak incentives to academic entrepreneurship* (Henrekson and Rosenberg, 2001)*;* (2) *weak knowledge and technology transfer* (European Commission, 2007; Bitard, Edquist and Hommen, 2008); (3) *lack of research funding* (Pavitt, 2000); (4) *bureaucratic organisational structures and processes* (Goldfarb and Henrekson, 2003); and, (5) *scientific leadership in mature fields of science* (e.g., chemistry, physics, mathematics and engineering) rather than in newly emerging, fast-growth and highly-promising fields (e.g., ICTs, medical and life sciences) (Bonaccorsi, 2007; Herranz and Ruiz-Castillo, 2013). However, subsequent studies show, among other things, that the European scientific system is more commercially-minded than previously believed. For instance, Conti and Gaule (2011) find that technology transfer offices at European universities are as productive (in terms of licence agreements) as their counterparts in the US. Similarly, other studies suggest that the birth rate of academic spin-off firms is higher in some European countries than, for instance, in the US (Jacobsson, Lindholm-Dahlstrand and Elg, 2013).

In summary, the relevant literature on innovation paradoxes implies that, while some 'blocking mechanisms' to regional productivity-growth may reside in the regional scientific base, there is also a need to systematically consider 'dominant beliefs', and the myths that often surround them, regarding the efficiency of regional scientific institutions prior to introducing initiatives aimed at redressing possible inefficiencies.

Regional innovation studies

Prompted by the emergence of endogenous growth theory in the 1990s, a number of regional growth studies have sought to quantify the relationship between R&D, regional productivity and growth (Acs and Varga, 2002; Bilbao-Osorio and Rodriguez-Pose, 2004; Crescenzi, 2005; Döring and Schnellenbach, 2006; Izushi, 2008; Audretsch and Keilbach, 2008). Central to this line of research is the assumption that R&D investments boost regional productivity through the knowledge spillover mechanism (Anselin, Varga and Acs, 1997; Breschi, 2001). Similarly, evolutionary growth theory confirms the significance of R&D activities for regional growth (Boschma and Lambooy, 1999). However, from an evolutionary economic standpoint, the link between R&D and regional productivity and growth is, in principle, a matter of *quality* rather than *quantity*.

Innovation is a key source of novelty creation in the economic system (Nelson and Winter, 1982; Castellacci, 2007). From an evolutionary standpoint, innovative activities embed two main types of variety in regional economies: *unrelated knowledge variety*, which is not directly related to the core knowledge expertise in a region; and *related knowledge variety*, which is directly related to the core knowledge expertise in a region (Frenken, Van Oort and Verburg, 2007; Boschma and Iammarino, 2009; Neffke, Henning and Boschma, 2011). While both types of knowledge variety are necessary for achieving resilient

[3] The European paradox refers to the inability of the European Union (EU) to transform the results of promising technological research and skills into innovations and competitive advantage (European Commission, 1995, p.5).

long-term regional growth (Simmie and Martin, 2010; Tsvetkova and Vermeulen, 2021), related knowledge variety is, however, more conducive to regional productivity and growth than unrelated knowledge variety (Box 1) (van Oort, de Geus and Dogaru, 2015; Boschma, 2017).

Box 1. Exploring related knowledge variety in regions: The promise of exaptation

What do successful innovations such as the energy drink Lucozade, Edison's phonograph, and laser technology have in common? In short, these innovations were initially created to serve a different purpose than the one that made them commercially successful. Exaptation refers to the process of identifying a latent function in an already existing artefact such as technology, product, process and organisational model (Dew, Sarasvathy and Venkataraman, 2004). Andriani, Ali and Mastrogiorgio, (2017) show that exaptation is an essential mechanism of new-idea generation in the pharmaceutical industry; for instance, 42% of new functions are derived from existing drugs rather than from new R&D. Gaddefors, Korsgaard and Ingstrup (2020) document in a longitudinal case study analysis of a rural region in Sweden how exaptation-orientated entrepreneurship initiatives have triggered a positive path of regional development.

Source: Author's elaboration.

Of significance to our understanding of how related knowledge variety is transformed into productivity gains and regional growth is the regional university. The university not only acts as a 'supplier' of highly-skilled human capital in regional labour markets (Smith and Waters, 2011 and 2021), but also constitutes a significant cognitive 'input' to regional innovation activities (Anselin, Varga and Acs, 1997; Smith, 2007; Benneworth et al., 2009; Huggins and Johnston, 2009; European Commission, 2014; Heaton, Siegel and Teece, 2019). Benneworth (2007), for instance, documents how regional actors in a peripheral region of the UK created a shared understanding around the university as a 'glocal' repository of knowledge (see, also, Benneworth et al., 2009).

Furthermore, by creating and bringing state-of-the-art global knowledge, as well as nurturing novel scientific ideas and creativity, the university stimulates and supports entrepreneurial ventures, especially in the early stages of the entrepreneurial process (Smith, 2007; Uyarra, 2010; Trippl, Sinozic and Lawton Smith, 2015; Heaton, Siegel and Teece, 2019). The burgeoning literature on entrepreneurial ecosystems confirms, among other things, the significance of universities in creating and sustaining high rates of innovative start-ups and productivity in regional economies (Stam, 2015; Acs et al., 2017; Heaton, Siegel and Teece, 2019; Tsvetkova, Schmutzler and Pugh, 2020). For instance, academic entrepreneurship (e.g., spin-offs) acts as a conduit between the regional research base and the regional economic base (Acs and Plummer, 2005; Smith, 2007; Audretsch and Keilbach, 2008; Miller and Acs, 2013). In doing so, it overcomes regional obstacles to knowledge transfer (Box 2). Entrepreneurship also encompasses novel and more efficient ways of allocating regional assets – for instance, introducing new and more efficient ways of (re-)organising and upgrading, as well as destroying, the same regional resources that sustained its survival and success in the past (Schumpeter, 1934; Audretsch, 2009; Smith, 2018). Lastly, when socially-inclusive, entrepreneurship can alleviate regional poverty and inequality by, for instance, enhancing social mobility, reducing informal work and creating decent jobs, although this seems to depend on the type of entrepreneurship, product offerings, regional and national institutional factors (Bruton, Ketchen and Ireland, 2013; Lee and Clarke, 2019; Alvarado and Servantie, 2020; Fragkandreas, 2021a; Lee and Rodríguez-Pose, 2021).

Box 2. Campus-based entrepreneurial ecosystems: The University of Chicago

Why do so many successful high-tech firms (e.g., Google, Facebook, Microsoft) were conceived and founded by university students rather than by business managers? According to Miller and Acs (2017) the contemporary university campus acts as an entrepreneurial ecosystem, offering a set of valuable resources to early-stage entrepreneurs such as knowledge, liberty, diversity and creativity. To illustrate the role of campus as an entrepreneurial ecosystem, Miller and Acs (2017) analyse one of the main campuses of the University of Chicago, and the output produced by that campus ecosystem since the early 1990s. Students at this university have created numerous high-growth start-ups (see Table 2 in Miller and Acs, 2017), such as the e-commerce firm, Groupon, which has, as of early June 2021, a market capitalisation of 1.3 billion USD (source: Bloomberg.com). Drawing on their previous work (e.g., Miller and Acs, 2013), Miller and Acs's analysis implies that regional initiatives need to be introduced to sustain and enhance the entrepreneurial potential of the campus, with a specifical focus on entrepreneurship that could solve and address pressing regional challenges such as environmental sustainability, inclusive growth and productivity.

Source: Author's elaboration.

The discussion in this section has touched upon several regional mechanisms through which the regional research base contributes to both innovation and productivity. However, the policy implications that derive from this section fit better with regions possessing a well-developed regional base rather than with regions which have a relatively weak or underdeveloped research base. As will be discussed in the next two sections of this paper, innovative firms in regions with low research intensity organise the innovation process differently than in the research-intensive regions (Morgan and Nauwelaers, 2003; Isaksen and Karlsen, 2013; Radosevic, 2018; Eder, 2019). This, among other things, implies that a well-advanced regional research base does not constitute a necessary precondition for reaping significant productivity gains from innovation[4] (Capello and Lenzi, 2015; cf. Cortinovis and van Oort, 2019).

[4] For instance, Freeman's (1987) seminal analysis of the Japanese 'economic miracle' in the post-war period illustrates, among other things, that high rates of productivity growth and global technological leadership can be achieved even when the research system is relatively underdeveloped.

3 Regional economic base: Research and policy implications

This section summarises key research developments in the literature on both global productivity decline and innovation paradoxes before it conjoins them with key insights derived from the field of regional innovation studies. It focuses on specific activities and inabilities of the (regional) economic base in general, and firms in particular. Four key regional policy implications emanate from the discussion in this section.

- Encouraging firms to combine different knowledge bases (e.g., analytical, synthetic and symbolic bases) and modes of innovation (e.g., science, technology, doing, using and interacting) could improve regional productivity;
- Enabling access to the prevailing knowledge base and mode of innovation in a region could increase regional business dynamism by, for instance, leading to a more even dispersion of innovative capability and opportunities among regional firms;
- Supporting intrapreneurship in regionally-embedded superstar firms could lead to productivity spillovers through, for instance, the diffusion of more efficient business models;
- Combining participation in global value chains with local clustering initiatives could create positive multiplier effects.

Productivity slowdown research

Declining business dynamism is increasingly being seen as a critical determinant of declining productivity rates in the OECD economies (Decker et al., 2017; Crafts, 2018; Goldin et al., 2020). As measured by the Herfindahl index, industry concentration has increased in the US by 70% in the 1980-2000 period (Peltzman, 2014). Similarly, both entry and exit business rates have fallen since the 1980s in the US: from 0.13 in 1980 to 0.09 in 2015 (Gutiérrez and Philippon, 2017). Declining business dynamism is also reflected in growing productivity gaps among firms. Andrews et al. (2016) find, in a sample of 23 OECD countries, that superstar firms (the top 5% most productive firms) have increased their productivity by around 40% on average since 2010, while the rest of the firms have experienced much slower or declining productivity growth. In a recently published study, Tang and Wang (2020) show that much of the productivity slowdown in Canada is due to the retreat of large and high-productivity firms from the aggregate technological frontier (i.e., the maximum level of productivity potential related to firm-specific technology development).

Overall, the existing literature on the productivity slowdown suggests that declining productivity at the regional level can, among other things, be attributed to the concentration of regional productivity in a few superstar firms, as well as the fact that both superstar firms and other less productive firms pursue ‘retreat-from-the-technological-frontier’ innovation strategies.

Innovation paradoxes research

Emerging from a debate surrounding the future of the Swedish economic model, the Swedish paradox refers to the observation that outstanding investments in innovation-related activities generate little economic return in terms of new products, competitiveness, growth and employment (Edquist and McKelvey, 1998; Jacobsson, Lindholm-Dahlstrand and Elg, 2013). Among the most often-cited explanations for the paradox in question is the concentration of innovative capabilities of the Swedish economy in a small group of Swedish multinational enterprises (MNEs) (Edquist and McKelvey, 1998; Bitard, Edquist and Hommen, 2008). Despite conducting the majority of R&D activities at home, Swedish MNEs produce new products elsewhere in the world through, for instance, global value chains and production networks (Bitard, Edquist and Hommen, 2008; Chaminade and Plechero, 2015). Hence, innovation made in Sweden pays off, in terms of productivity gains and jobs, in other countries.

In addition to this, MNEs, in both Sweden and Europe, seem to have been unable to take advantage of promising scientific findings and new technologies. Dedrick and Kraemer (2015) showed that, while European (mainly French and German) scientists were the original inventors of the giant magneto-resistance (GMR), the lion's share of the economic benefits (e.g., productivity, employment, and profits) from the commercial exploitation of the technology in question was captured by firms located in the US and Japan. Dedrick and Kraemer (2015) attributed this loss of value to the weak absorptive capacity of European high-tech firms (see, also, Tijssen and van Wijk, 1999).

In summary, innovation paradoxes research suggests that the increasing dependence on a small number of (technologically locked-in) large firms can negatively affect the long-term productivity potential of national economies, and thus also of their constitutive regional economies.

Regional innovation studies

Since the late 1980s, the regional scale has been acknowledged as the place where innovative activities are conceived and (re-)produced through regional innovation networks, clusters and innovation systems (Storper, 1997; Lunduall and Borras, 1998; Moulaert and Sekia, 2003; Asheim, Smith and Oughton, 2011; Tsvetkova, Schmutzler and Pugh, 2020). Regions facilitate, as well as constrain, the ability of innovative firms when it comes to combining three knowledge bases, namely *analytical*, *synthetic* and *symbolic* knowledge (Asheim and Coenen, 2005; Asheim, 2007; Asheim, Moodysson and Todtling, 2011). Knowledge bases constitute essential 'inputs' to two main modes of innovation in firms: the *science, technology, innovation* (STI) mode, which mainly consists of analytical knowledge such as science-based learning, R&D activities and codified knowledge (e.g., patents); and the *doing, using, interacting* (DUI) mode which relies mainly on synthetic and symbolic regional knowledge bases, as well as on local user-producer interactions, tacit knowledge, experience-based, interactive learning and past competencies (Jensen et al., 2007; Isaksen and Karlsen, 2013; Radosevic, 2018). Mastering one of these two modes of innovation is often a 'collective achievement', i.e., a property of regional clusters and sectors rather than individual firms (Pavitt, 1984; Isaksen and Karlsen, 2013). However, market-leading and export-oriented innovative firms, including fast-growing start-ups, often utilise both modes of innovation (Jensen et al., 2007; Fitjar and Rodríguez-Pose, 2013; Doloreux et al., 2020; Alhusen and Bennat, 2021). Combining both modes of innovation (including their associated regional knowledge bases) is necessary to create and capture economic value from investments in innovation, especially from digital innovation (Jensen et al., 2007; Herrmann and Peine, 2011; Nambisan, 2017; Autio et al., 2018; Teece, 2018).

However, due to historical and institutional reasons (Martin, 2003; Martin and Sunley, 2006), most regions are endowed with an (hard and soft) infrastructure supportive of either STI or DUI activities, but rarely both[5] (Boschma and Weterings, 2005; Asheim, 2007; Fitjar and Rodríguez-Pose, 2013; Isaksen and Karlsen, 2013; Doloreux et al., 2020). In order to compensate for mode-specific deficits in a region, firms exploit knowledge from different parts of the world (Bathelt, Malmberg and Maskell, 2004; Chaminade and Plechero, 2015; Isaksen and Trippl, 2017). Innovative firms, and is the case with universities and research institutes, are central to the process of creating and absorbing global, top-notch knowledge (Archibugi and Iammarino, 1999; MacKinnon, Cumbers and Chapman, 2002; Trippl, Sinozic and Lawton Smith, 2015; Isaksen and Trippl, 2017). In doing so, the activities of innovative firms contribute to the technological upgrading of regional clusters and firms, as well as improving the absorptive capacity of laggard firms through, for instance, localised learning and knowledge spillovers (Bathelt, Malmberg and Maskell, 2004; Giuliani, 2005; Blažek, 2016; Radosevic, 2018).

Nonetheless, being well-connected to the global order of things does not, automatically, convert into significant regional socio-economic benefits such as higher living standards, productivity, decent jobs and resilient growth. A major challenge that most regions are currently facing is how to combine participation in global value chains and production networks with local multiplier effects (Yeung, 2009; Boschma and Iammarino, 2009; Radosevic, 2018; Crescenzi, Harman, and Arnold, 2018). Although the extent to which participation in global value chains (GVCs) can be associated with meaningful local benefits depends heavily on how local firms, clusters and regional assets have been 'strategically coupled' with and inserted into GVCs (Yeung, 2009; Yeung, 2021), including the prevailing governance structure of the latter (Gereffi, Humphrey and Sturgeon, 2005; Blažek, 2016), the degree and type of embeddedness of global lead firms in a region are of significance when it comes to creating and sustaining over time 'sticky' local economic multipliers in 'slippery times' (Markusen, 1996; Hess, 2004; Crescenzi, Harman, and Arnold, 2018; Radosevic, 2018). For instance, Carrillo (2004) documented how local clustering policies in the State of Chihuahua in Mexico helped to translate the production strategies of global automotive firms into productivity gains for local automotive suppliers, while also significantly improving the working conditions in local plants [6].

Undoubtedly, the multinational enterprise (MNE) is the most significant actor in generating and orchestrating GVCs (Gereffi, Humphrey and Sturgeon, 2005; Yeung, 2009; Crescenzi, Harman, and Arnold, 2018). Traditionally, the presence of MNEs in a region has been associated with significant benefits such as learning, knowledge flows and productivity spillovers to regional firms (see also Box 3) (Mudambi and Swift, 2012; Iammarino and McCann, 2013; Navaretti and Venables, 2013; Bournakis, Papanastassiou and Pitelis, 2019). However, not everything is so rosy when it comes to the contribution of MNEs in regional economies. Christopherson and Clark's (2007a; 2007b) study on regional innovation networks in Rochester (New York State) shows that the innovation agenda of MNEs often diverges significantly from that of innovative SME, thus leading to 'local contests and power struggles' when it comes to accessing value-producing regional resources such as highly-skilled labour, scientific knowledge and regional governmental funds. Skill shortages are one of the main obstacles to the development and commercial exploitation of (digital) innovation (Acemoglu, 2002; Jackson et al., 2016; Eder, 2019; OECD, 2019b). Box 4 tells the story of a successful initiative introduced by 29 SMEs in the region of Braunschweig in

[5] For instance, metropolitan regions tend to provide a favourable support system to innovative firms that excel at STI activities (Cooke, 2002; Diez, 2002; Niosi and Bas, 2003; Brandt et al., 2009; Blažek and Žížalová, 2010). In contrast, intermediate and peripheral regions tend to host firms and clusters undertaking innovation through the DUI mode (Isaksen and Karlsen, 2013; Trippl, Asheim and Miörner, 2016; Radosevic, 2018; Eder, 2019).

[6] Similar examples for regions in Central and Eastern European countries can be found in Radosevic (2018).

Northern Germany. This initiative enabled regional SMEs to attract and retain highly-skilled labour in a region where the innovation agenda has, for several decades, been shaped by the activities of MNEs.

Box 3. Stimulating productivity spillovers: Is intrapreneurship in super-star firms a viable option?

Intrapreneurship (also known as corporate entrepreneurship and corporate venturing) refers to entrepreneurship within an existing organisation (Antoncic and Hisrich, 2003; Bosma, Wennekers and Stam, 2010). One particularly interesting type of intrapreneurship is 'nascent intrapreneurship' (Parker, 2011) i.e., when new business opportunities are exploited by starting a new venture (e.g., business unit, subsidiary or spin-off firm) for or within an existing firm (Lechevalier, Nishimura and Storz, 2014). As far as the productivity slowdown is concerned, encouraging nascent intrapreneurship in superstar firms could not only increase the entrepreneurial potential of a region, but could also boost regional productivity through, for instance, knowledge and productivity spillover effects. Intrapreneurs often imitate and further advance existing efficient business models (Lechevalier, Nishimura and Storz, 2014). Unlike other types of entrepreneurship, which leverage human and social capital to sell directly to customers, intrapreneurs commercialise unique new opportunities which they sell to other firms in the region (Parker, 2011).

Source: Author's elaboration.

Box 4. "The battle for high-skilled labour has begun" – the mechanical engineering co-operative in the region of Braunschweig, Germany

Largely unknown among the generic public, the region of Braunschweig is the most R&D-intensive region of Europe. Despite being a small (approximately 1.2 million inhabitants), peripheral region, more than 8.5% of the regional gross domestic product (GDP) (EUR 5.9 billion) was dedicated to R&D activities in 2017, which is nearly three times higher than the R&D investment rate of Germany (3.1%) and four times that of the EU28 (2.0%). Similarly, the European regional innovation scoreboard consistently ranks the region of Braunschweig in the top 30 best-performing regions in Europe (Fragkandreas, 2013; European Commission, 2019). Braunschweig's impressive innovation performance is due to the existence of an 'organisationally-thick' regional innovation system (Brandt et al., 2009; Krätke, 2010; Fragkandreas, 2021b). The latter consists of seven innovative MNEs (e.g., Alstom SE, MAN SE, Nordzucker AG, Robert Bosch GmbH, Salzgitter AG, and Volkswagen AG), more than 250 innovative firms (including several 'hidden champion' firms), four research-active universities (educating more than 33 000 students per year), 27 research institutes (employing more than 16 000 researchers), and numerous regional development agencies, business incubators, business angels and local banks (Fragkandreas, 2021c; Fragkandreas, 2021b).

Considering the above, one would certainly expect an abundance of skilled labour in the region of Braunschweig. However, the opposite is true. As a CEO of a high-tech firm put it, "the main difficulty for us as a company is to find and to keep high-qualified personnel such as programmers and that is the main challenge for every company in the region of Braunschweig" (own interview). To address skill shortages in the region, in the late 2000s, 29 mechanical engineering firms created the cooperative engineering network (in brief, KIM e.V.). One of the primary purposes of this cooperative is to ensure

full-time, long-term employment for skilled labour (source: kim-braunschweig.de). Firms exchange skilled labour based on their production needs. For instance, if a member firm has a staff surplus for a particular month, it shares its surplus staff with the other member firms. This 'win-win' model of employment is also reflected in the motto of the cooperative: "We are strong together". In addition, and in collaboration with local universities, firms offer and finance vocational training in several subjects (e.g., plant mechanics, machine and system operators, information technology, logistics, precision mechanics, etc.). This not only helps firms to cope with skill shortages, but also leads to the creation of secure (medium- to long-term) employment for young skilled labour in a region that suffers from a declining population.

The experience in the region of Braunschweig offers some interesting insights into how skill shortages can be addressed effectively through, for instance, collective institutional entrepreneurship, local leadership and governance initiatives (see, also, Grillitsch and Sotarauta, 2020).

Source: Author's elaboration.

4 Regional innovation systems: Research and policy implications

Since the early 1980s, numerous studies have shown that innovation does not take place in a linear fashion or occur exclusively within the boundaries of the innovation firm—for instance, beginning with R&D activities before it reaches the market through production, marketing and sales (Kline, and Rosenberg, 1986; Powell, Koput and Smith-Doerr, 1996). Instead, innovation emerges through systemic, formal (market) and informal (non-market), interactions among a wide array of actors, such as innovative firms, suppliers, users, universities, research institutes, government organisations, regulatory bodies, banks and venture capitalists (Nelson, 1993; Braczyk, Cooke and Heidenreich, 1998; OECD, 2002; Edquist, 2005; Storz, 2008). In short, innovation emerges in innovation systems rather than in innovative firms. However, despite providing one of the cornerstone assumptions in the fields of innovation studies and policy (McCann and Ortega-Argiles, 2013; Edler and Fagerberg, 2017), the systematic character of innovation has been largely overlooked by the extant research on the productivity slowdown.

This section summarises key aspects of research on innovation paradoxes and regional innovation studies by examining the *inefficient innovation systems hypothesis*. In short, this hypothesis states that it is a number of structural problems in (regional) innovation systems, rather than solely in universities, research institutes and firms that hinder the ability of firms and regions to either reap significant productivity gains from innovation or cope with the destructive effects of the latter.

Overall, the discussion in this section derives the following four regional policy implications:

- Addressing issues of 'organisational thinness' in regional innovation systems of peripheral and less developed regions could help the latter to narrow down innovation and productivity gaps with more innovative and productive regions;
- Tackling 'fragmentation' problems in regions could attenuate the innovation-productivity nexus by, for instance, bringing closer a set of geographically close but cognitive distant regional actors;
- Facilitating the diversification and renewal of highly specialised regions could not only prevent negative lock-ins but could also facilitate the exploration of new, more productive, yet resilient paths of regional growth;
- Demand-oriented regional innovation initiatives (e.g., public procurement for innovation) could be used to stimulate interactions among regional firms and support organisations, as well as for boosting the innovative capability of peripheral regions.

Innovation paradoxes research

One of the most popular explanations for the occurrence of innovation paradoxes, especially at the national level, is the inefficient innovation system (IS) hypothesis (Niosi, 2002; Bitard, Edquist and Hommen, 2008; Fragkandreas, 2017). Edquist and McKelvey (1998) were the first to propose that the Swedish paradox is

caused by inefficiencies in the Swedish IS. Building upon Edquist and McKelvey's hypothesis, Bitard et al. (2008) examined, at length, the inefficient IS hypothesis in Sweden. Their analysis concentrated upon five main sets of activities: *knowledge inputs to innovation* (e.g., R&D activities); competence building (e.g., training and education); *demand-side factors* (e.g., the formation of new markets); *provision of constituents* (e.g., entrepreneurship, networking, interactive learning and institutions); *support services for innovation* (e.g., incubating, financing and consulting activities); and *innovation policies* related to the above activities. The findings illustrate that the Swedish IS performs exceptionally well in some activities related to knowledge inputs and poorly in many other activities related to the development, use and diffusion of innovation (Bitard, Edquist and Hommen, 2008; Edquist, 2011).

More recently, Jackson et al. (2016) extended our understanding of the inefficient IS hypothesis by investigating the Austrian innovation paradox, i.e., Australia performs poorly when it comes to translating innovation inputs into innovation outputs. Based on the (critical realist) approach to causal mechanisms, these authors identified six causal mechanisms responsible for Australia's poor performance:

- *Mechanism 1: lack of funding*. Australian firms do not have the funding required to allocate resources to the development of new products and services;
- *Mechanism 2: shortage of analytical skills*. Lack of STEM (science, technology, engineering and mathematics) skills restricts the ability of Austrian firms to engage in the development and commercialisation of innovation;
- *Mechanism 3: low managerial capability*. Australian managers lack soft skills and creative techniques to tackle key complexities in the innovation process;
- *Mechanism 4: low value-adding specialisation*. The dominance of simple low value-adding industry activities leads to low demand for promising innovation activities;
- *Mechanism 5: weak collaboration*. Low levels of firm–firm and firm–support organisation collaboration inhibit synergistic relationships and innovation development;
- *Mechanism 6: entrepreneurial culture*. The national culture undervalues entrepreneurship.

The study of Jackson et al. (2016) made an essential contribution to our understanding of innovation paradoxes. The emphasis on causal mechanisms, rather than only on statistically significant associations among variables (the conventional methodological approach), confirms not only the multi-determined nature of innovation paradoxes, but also has clear implications for what kinds of policy initiatives need to be introduced to address the relative underperformance of the Australian IS.

In summary, the extant innovation paradox research suggests that the global productivity slowdown may also be due to the structural issues and flaws in national innovation systems, which limit the ability of firms to benefit from promising technologies such as artificial intelligence and digitalisation. Since the innovative capabilities of national innovation systems are often concentrated in a few regions (Asheim and Gertler, 2005; Feldman and Kogler, 2010), this raises the possibility that it is the inefficiencies in regional innovation systems that could be a key determinant of declining productivity in OECD countries. It is this possibility that concerns the remainder of this section.

Regional innovation studies

Originating in the late 1990s as a synthesis between the early research on national innovation systems and territorial innovation models (e.g., innovative milieux, industrial districts, local production systems, etc.), the regional innovation systems (RISs) approach is, by now, one of the most utilised theoretical frameworks for analysing the uneven geographical distribution of innovative activities in the OECD economies (Moulaert and Sekia, 2003; Asheim, Smith and Oughton, 2011; Asheim, Isaksen and Trippl, 2019). It also constitutes an essential source of inspiration for designing regional innovation policies (for

instance, the smart specialisation agenda) whose aim is to stimulate the innovative capability, competitiveness and paths of development in regional economies (Asheim, Cooke and Boschma, 2006; McCann and Ortega-Argiles, 2013; Asheim, 2019). Central to the RISs approach lies the thesis that systemic interactions among regional actors are central to creating and reproducing the uneven geography of innovation in modern-day economies (Asheim and Gertler, 2005). In particular, the RISs approach consists of regionally-embedded interactions among innovating firms and support organisations (e.g., universities, research institutes, regional policy organisations, consultants, intermediaries, etc.) facilitating the development and diffusion of knowledge, learning and innovation in a region (Cooke, 2001; Asheim, Isaksen and Trippl, 2019).

Although RISs are essential when it comes to sustaining high levels of regional innovation performance, they can also impede the commercial exploitation and productivity potential of promising innovative activities (Isaksen, 2001; Tödtling and Trippl, 2005; Martin and Trippl, 2014). This is due to a set of *systemic problems*, the most common of which are the following three types:

1. ***Organisational thinness problems*** occur when a critical mass of innovative firms and support organisations are either absent or poorly developed in a region. This type of problem is most commonly encountered in peripheral regions (Doloreux and Dionne, 2008; Isaksen and Karlsen, 2013; Asheim, Isaksen and Trippl, 2019; Eder, 2019). The latter often lack a critical mass of innovative firms in the same sector – hence, neither the condition of agglomeration economies nor the conditions of local networking, interactive learning and capacity building can take place in a cumulative manner (Tödtling and Trippl, 2005; Isaksen and Karlsen, 2013; Eder, 2019). Organisational thinness has a significant impact on regional productivity, as several complementary assets to the innovation process need to be sourced, at an extra cost, from organisations outside the region (Eder and Trippl, 2019). Lack of trust among local actors, weak collective leadership, underdeveloped infrastructure and weak institutional capacities, including a weak capacity to absorb extra-regional funds, are factors which further reinforce the problem of organisational thinness in peripheral regions (Oughton, Landabaso and Morgan, 2002; Komninaki, 2015; Radosevic, 2018; Eder, 2019). One way of mitigating organisational thinness problems in regions is by creating multi-scalar synergies among regional and national innovation intermediaries (Box 5). Another strategy is to use public procurement policies as a means of stimulating demand for new products and services (Box 6).

Box 5. Regional innovation intermediaries in Northern Finland

Innovation intermediaries play an important role in regional innovation activities in general, and peripheral regions in particular. By linking cognitively-distant actors, innovation intermediaries facilitate technology transfer, commercialisation of new ideas and resources exchange (Howells, 2006; Nauwelaers, 2013). They also provide counselling, consultation and financial support to innovative firms. In doing so, they fill important organisational and institutional voids in the innovation development process, especially in peripheral regions where regional innovation networks and learning are weak. Inkinen and Suorsa (2010) showed in their study of 168 high-tech firms in Northern Finland that fast-growing innovating firms make use of financial resources from both regional and national innovation intermediaries. The experience in Northern Finland also underlines that local innovation intermediaries are more likely to address organisational thinness problems, including weak agglomeration economies, when they work closely with the national ones.

Source: Author's elaboration.

Box 6. Regional public procurement for innovation: The case of Galicia

Innovation policies have long sought to stimulate supply-side factors (e.g., R&D incentives, science parks, incubators, provision of human capital and research infrastructure) as the primary domain of policy action (Edler and Fagerberg, 2017). However, and as illustrated by the growing number of demand-side innovation policies (e.g., public procurement of innovation initiatives), public procurement could also be used to stimulate the development of new knowledge, capabilities, innovation and new markets, especially in peripheral regions where demand for new products is often week, lying outside the region—hence leading to an early exodus of innovative firms, loss of productivity, employment and growth in peripheral regions (Uyarra et al., 2017; Sánchez-Carreira, Peñate-Valentín and Varela-Vázquez, 2019; Eder and Trippl, 2019; Zabala-Iturriagagoitia, 2021). Uyarra et al. (2020) analyse the case of Galicia in Spain, seeking to find out how public procurement for innovation (PPI) initiatives were institutionalised in the innovation agenda of a rural, peripheral coastal region of Spain. Galicia is a special case as, since the 2013, it has introduced a number of PPI initiatives in health (Sánchez-Carreira, Peñate-Valentín and Varela-Vázquez, 2019; Zabala-Iturriagagoitia, 2021). Funded by the European Regional Development Fund (ERDF) with an amount of EUR 90 million, Galicia introduced two main PPI projects, the InnovavaSaude and Hospital 2050, both of which include a total of 23 subprojects, aimed at strengthening the innovative capability of the regional economy by, for instance, creating innovation-oriented synergies among regional SMEs and the Galician Healthcare System (Uyarra et al., 2020; Zabala-Iturriagagoitia, 2021). The experience in Galicia shows, among other things, that both SMEs and governmental organisations participating in PPI projects develop new skills and capabilities, even when PPI projects are not successful (Sánchez-Carreira, Peñate-Valentín and Varela-Vázquez, 2019; Zabala-Iturriagagoitia, 2021).

Source: Author's elaboration.

2. ***Regional fragmentation problems*** occur when the regional knowledge exploration and exploitation subsystems are 'organisationally-thick' and located nearby but, due to the cognitive diversity among actors, this results in lower levels of collective learning, intra-regional knowledge exchange, absorptive capacity and innovation (Box 7). Fragmentation problems consist of hard and weak network deficiencies, especially when there is a significant lack of connectivity among focal (triple-helix) regional actors (Woolthuis, Lankhuizen and Gilsing, 2005; Tödtling and Trippl, 2005). This systemic problem is, primarily, encountered in metropolitan regions; however, intermediate and peripheral regions can also exhibit significant network deficiencies (Blažek and Uhlíř, 2007; Eder, 2019; OECD, 2019b).

Box 7. Overcoming fragmentation in Metropolitan RISs: The significance of "Type 2" firms

How can a new cluster emerge in a fragmented RIS? This question drives the study by (Blažek and Žížalová, 2010) in the metropolitan region of Prague. Previous research has shown that the metropolitan RIS of Prague is quite fragmented, resulting in weak local networking, cooperation and interactive learning among regional innovative firms and support organisations (Blažek and Uhlíř, 2007). Fragmentation acts as a blocking mechanism to the emergence of new technologies, clusters and sectors (Bergek et al., 2008; Martin and Trippl, 2014). Yet, since the 2000s, the region of Prague has been home to the largest cluster of biotech firms in the Czech Republic: it is the most central node in

the Czech biotech sectoral innovation system. For instance, more than 47% of R&D activities in the Czech biotech sector is conducted by biotech firms and scientific institutions in the region of Prague (source: www.gate2biotech.com). Blažek and Žížalová (2010) found that the emergence of the biotech cluster in Prague was mainly due to the activities of a specific type of regional biotech firms which they call 'Type 2'. Unlike 'Type 1' firms, which mainly use international knowledge sources to innovate, Type 2 firms make an intensive use of local knowledge sources. This type of biotech firms has strong ties to regional research organisations. Blažek and Žížalová (2010) show that most Type 2 biotech entrepreneurs were at some point employed by or engaged academically with one of the regional scientific institutions of Prague. One of the key implications that emanate from Blažek and Žížalová's study is that Type 2 firms are of significance to address fragmentation issues in metropolitan regions.

Source: Author's elaboration.

3. ***Regional negative lock-in problems*** occur when regional firms and clusters cannot respond swiftly to rapidly changing market needs and technological developments, including regulatory changes (Woolthuis, Lankhuizen and Gilsing, 2005; Cho and Hassink, 2009; Schmidt et al., 2020). This systemic problem is encountered in regions in developing countries and old industrial regions in developed countries (Martin and Trippl, 2014; Schmidt et al., 2020). Locked-in regions are often 'organisationally thick' and highly specialised in one cluster or industry. Negative technological lock-ins inhibit the capacity of firms to engage in promising innovation activities at the technological frontier of their corresponding sector, thus keeping both firms and regions locked in existing paths of declining productivity and non-resilient growth (Cho and Hassink, 2009; Schmidt et al., 2020). While there are different routes to transform a regional economy through, for instance, cluster renewal and new path creation (see Box 8), the transition process is a very demanding endeavour (Trippl and Otto, 2009; Blažek et al., 2013; Boschma, 2017; Grillitsch and Sotarauta, 2020). Trippl and Otto (2009) analyse comparatively the cluster-based renewal in two old industrial regions, Styria in Austria and Saarland in Germany. The analysis confirms that the transition process is a very demanding endeavour, requiring a complex interplay of regional factors such as firm strategies, changes in the regional knowledge infrastructure, institutional innovation, policy leadership and learning processes.

Box 8. Path transformation and system reconfiguration in West Sweden

The innovation capability of the Swedish automotive industry is mainly concentrated in the region of West Sweden. The region is home to large automotive firms (e.g., Volvo Cars, Volvo AB, HCL Technologies Sweden, CEVT, Autoliv and IAC), a number of automotive suppliers from various parts of the value chain, whose activities are supported by a 'thick' regional support structure (e.g., Chalmers University of Technology, science parks, and intermediaries). One of the main competitive strengths of the regional automotive industry in West Sweden has long been in the field of active safety technology, namely in technologies designed to avoid car accidents. However, the emergence of self-driving cars (SDCs) technologies and new players in the SDCs field (e.g., Google and Apple) required the formation of regional knowledge networks among a set of previously unconnected actors. This was necessary to ensure the fusion of knowledge from a variety of regional fields of competence, such as mechanics, electronics and information technology. To do so, leading regional actors (e.g., focal firms, regional governmental organisations and universities) engaged in three types of system reconfiguration activities in the RIS of West Sweden. First, they developed new and reinforced existing functions of the RIS in West Sweden by, for instance, creating new research labs, education programmes, test infrastructures,

funding schemes, and forming new intra-regional network linkages. Second, new inter-regional linkages were created to access system functions of other RIS in Sweden and the US (e.g., Silicon Valley). Lastly, there was transplantation of system functions (e.g., investment mobilisation and experimentation) from other RISs.

Source: https://www.vgregion.se/en/ Miörner and Trippl (2019) and Miörner (2020).

5 Validity: Key issues and policy implications

This section examines the 'validity' of the innovation-productivity paradox. In particular, it discusses the issues of empirical and theoretical validity of the paradox in question. Two policy-relevant implications emanate from the discussion in this section.

- 'Theory matters' – theory not only shapes our understanding of the regional aspects of the innovation-productivity paradox, but also defines the scope of 'appropriate' regional policy action;
- Identifying empirically the innovation-productivity paradox in a region constitutes a significant step in the process of diagnosing the underlying regional causes of the paradox in question.

Productivity slowdown research

One of the most often-cited explanations for the global productivity slowdown concerns the issue of productivity measurement, also known as the *mismeasurement hypothesis* (Carlaw and Lipsey, 2003; Syverson, 2017; Crafts, 2018; Goldin et al., 2020). Several researchers have alluded to the possibility that, due to structural change (e.g., the shift from a Fordist industrial to a Post-Fordist services-orientated economy), including the rise of the informal sector in several OECD economies, national accounts may fail to gauge productivity in the context of an increasingly digitalising economy, where intangible assets, rather than tangible ones, constitute a key driver of productivity growth (Dettori, Marrocu and Paci, 2012; Ahmad, Ribarsky and Reinsdorf, 2017; Crafts, 2018). Others criticise the use of total factor productivity (also known as the Solow residual) as a measure of technological progress, and thus also of innovation (Carlaw and Lipsey, 2003; Crafts, 2018). However, the scale of mismeasurement seems to be not large enough to account, on its own, for steadily declining rates of productivity in OECD economies (Ahmad, Ribarsky and Reinsdorf, 2017).

Important questions are also raised about the underlying theory that informs our understanding of the global productivity slowdown (Crafts, 2018; Goldin et al., 2020). From the standpoint of endogenous growth models, R&D and productivity are closely related, almost in a linear way (Romer, 1990; Grossman and Helpman, 1994). However, from the standpoint of evolutionary (neo-Schumpeterian) growth theory, the productivity impact of radical technological innovation is, by no means, linear and proportional, nor is it possible to achieve significant productivity gains from radical technological innovation in a short period (Freeman and Louçã, 2001; Fagerberg, 2003). The innovation process is fraught with significant technological and organisations challenges, while it is also facilitated and constrained by multi-scalar institutional arrangements (Nelson and Winter, 1982; Nielsen and Johnson, 1998; Freeman and Louçã, 2001; Perez, 2010; Bodrožić and Adler, 2018). David (1990) provided historical evidence confirming that it can take several decades for promising GPTs to be able to deliver significant productivity gains. For instance, Thomas Edison began the distribution of electrical power in New York City in 1882. However,

the most significant impact of electricity on labour productivity occurred in the 1920s, when electricity was used widely in industrial factories (David, 1990; Crafts, 2018).

To summarise, the existing literature on the productivity slowdown suggests that (a) the productivity slowdown is more likely to be the outcome of economic factors, rather than solely of methodological issues, and that (b) theory matters when it comes to conceptualising the paradox in question. Moreover, and as will be discussed shortly, innovation paradoxes studies have reached similar conclusions.

Innovation paradoxes research

Dosi, Llerena and Labini (2006) were among the first to raise and examine, in a systematic manner, the question of empirical validity regarding innovation paradoxes. Their analysis of the European paradox shows that Europe is, by no means, a leader in scientific research; hence, the notion of the European paradox cannot, in the opinion of Dosi et al., be empirically substantiated (see, also, Herranz and Ruiz-Castillo, 2013). While Dosi et al. (2006) addressed the empirical validity of the European paradox, Ejermo and Kander (2005) raised the question of the theoretical validity of innovation paradoxes. According to these authors, much of our understanding of innovation paradoxes has, either explicitly or implicitly, been informed by the scale effects assumption in endogenous growth theory, including the linear model of innovation, rather than by assumptions derived from alternative theoretical perspectives such as evolutionary growth theory (Ejermo and Kander, 2005; Fragkandreas, 2017). A corollary of this is that much of the discourse on innovation paradoxes often rests upon unrealistic assumptions regarding, for instance, the relationship between innovation, productivity and growth.

However, what seems to be interesting here is that, regardless of the theoretical perspective that one adopts, the underlying pattern which lies at the centre of any innovation paradox is that of 'high-input-low-output' (Zabala-Iturriagagoitia et al., 2007; Bitard, Edquist and Hommen, 2008; Fragkandreas, 2013; Fragkandreas, 2017). Bitard et al. (2008), for instance, noted that, despite being empirically contested (Ejermo, Kander and Svensson Henning, 2011), the notion of the Swedish paradox made evident that the national innovation system of Sweden requires much higher investments in innovation to achieve the same levels of productivity, competitiveness and welfare that other small innovative countries (e.g., Denmark, Ireland, The Netherlands and Norway) achieve with far fewer resources devoted to innovation (Bitard, Edquist and Hommen, 2008; Edquist, 2011). In this context, the Swedish paradox constitutes an opportunity to improve the entrepreneurial potential, functioning, structural composition and innovation policy design of the Swedish national innovation system, including its constituent regional innovation systems (Edquist, 2011; Edquist, 2019; Zabala-Iturriagagoitia, 2020); also given the fact that the performance of national innovation systems is heavily dependent upon, in the long-term, a synergistic relationship with its corresponding regional innovation systems (and vice versa) (Freeman, 2002; Chung, 2002; Asheim and Herstad, 2005; Lengyel and Leydesdorff, 2011; Porto-Gomez, Zabala-Iturriagagoitia and Leydesdorff, 2019).

Policy-relevant observations and implications

Two key policy implications derive from the discussion in this section: ***theoretical awareness*** and ***empirical identification***. Theoretical awareness refers to the extent to which one is aware of the theoretical perspective that, inevitably, informs his/her understanding of the regional dimension of the innovation-productivity paradox. To put it simply, 'theory matters' because it shapes how we conceptualise the relationship between innovation and regional productivity. It also has profound implications for what types of regional policies need to be introduced to boost the innovation-productivity nexus in OECD regions. For instance, if the relationship between innovation and regional productivity is conceptualised from the standpoint of endogenous regional growth theory, the primary domain of regional policy action

lies in the link between R&D investments and regional productivity, which, in the language of this paper, corresponds to the regional research base. However, if one takes an evolutionary-institutional economic perspective on the matter (e.g., regional innovation systems approach), the relationship between innovation and regional productivity is highly dynamic, causally complex, and, above all, a region-specific question, hence requiring not only an appropriate research design (Asheim, 2006) but also an appropriate policy rationale, as illustrated by, for instance, the Smart Specialisation framework (Foray, Morgan and Radosevic, 2018).

The second policy implication concerns the question of *empirical identification*, i.e., how do we know that an innovation-productivity paradox is present in a region? In general, four identification strategies can be used to explore the possible existence of an innovation-productivity paradox at the regional level (Table 2).

Table 2. Innovation-productivity paradox in OECD regions

Paradox identification strategies

Regional innovation activities	Regional productivity	
	Single-factor productivity measurement	***Multifactor productivity measurement***
Narrow measurement	Narrow-single factor (NFS) strategy	Narrow-total factor (NTF) Strategy
Broad measurement	Broad-single factor (BFS) strategy	Broad-total factor (BTF) strategy

Source: Author's elaboration based on Evangelista et al. (2002), Carlaw and Lipsey (2003), Smith (2005), Lundvall (2007), Brenner and Broekel (2011), Del Gatto, Di Liberto and Petraglia (2011), Hong, Oxley and McCann (2012), Capello and Lenzi (2015), Trippl et al. (2016), Ortega-Argiles and McCann (2021).

The first identification strategy – i.e., *narrow-single factor strategy* – utilises the standard measures of innovation (e.g., R&D investments, patent intensity and share of employment in knowledge-intensive sectors) to gauge regional innovation performance, and a single-factor productivity to measure (e.g., labour productivity) regional productivity growth (Izushi, 2008; Makkonen and Inkinen, 2013; Yu et al., 2021). Yu et al. (2021), for instance, used the NTF strategy to search for the extent to which the Swedish paradox applies in Chinese provinces. While one of the key strengths of NTF strategies is ease of accessing data, the NTF strategy is, as the name indicates, too narrow when it comes to measuring the diverse nature of non-R&D-intensive regional innovative activities. The second identification strategy – i.e., *narrow-total factor strategy*[7] – gauges innovation in a narrow manner by productivity through using a total factor productivity measure. For instance, Capello and Lenzi (2015) measured, in their study on European regions, regional productivity by using total multifactor productivity and patent intensity to assess regional innovation. The third identification strategy – i.e., *broad-single factor (BSF) strategy* – measures regional innovation performance in a broad way, i.e., by using a set of indicators based on an average weighted score of several other innovation indicators (Trippl, Asheim and Miörner, 2016; European Commission, 2019). Regional productivity is measured as a single factor (e.g., regional labour productivity). Fragkandreas (2013), for instance, used data from the European regional innovation scoreboard and regional labour productivity from the Eurostat to show that some of the most innovative regions in Europe exhibit declining regional labour productivity, employment and growth. The last strategy – i.e., *broad-total factor (BTF) strategy* – measures regional innovation performance in a broad way, and regional productivity through a total factor measurement strategy. For instance, Zabala-Iturriagagoitia et al. (2007) used the

[7] Estimating total factor productivity has long been a controversial issue in the productivity literature. An overview of three main approaches (e.g., Solow residual, growth accounting, Cobb-Douglas production function, and data envelope analysis) to estimating the total factor productivity of economic units can be found in Carlaw and Lipsey (2003), Dettori, Marrocu and Paci (2012), and Capello and Lenzi (2015).

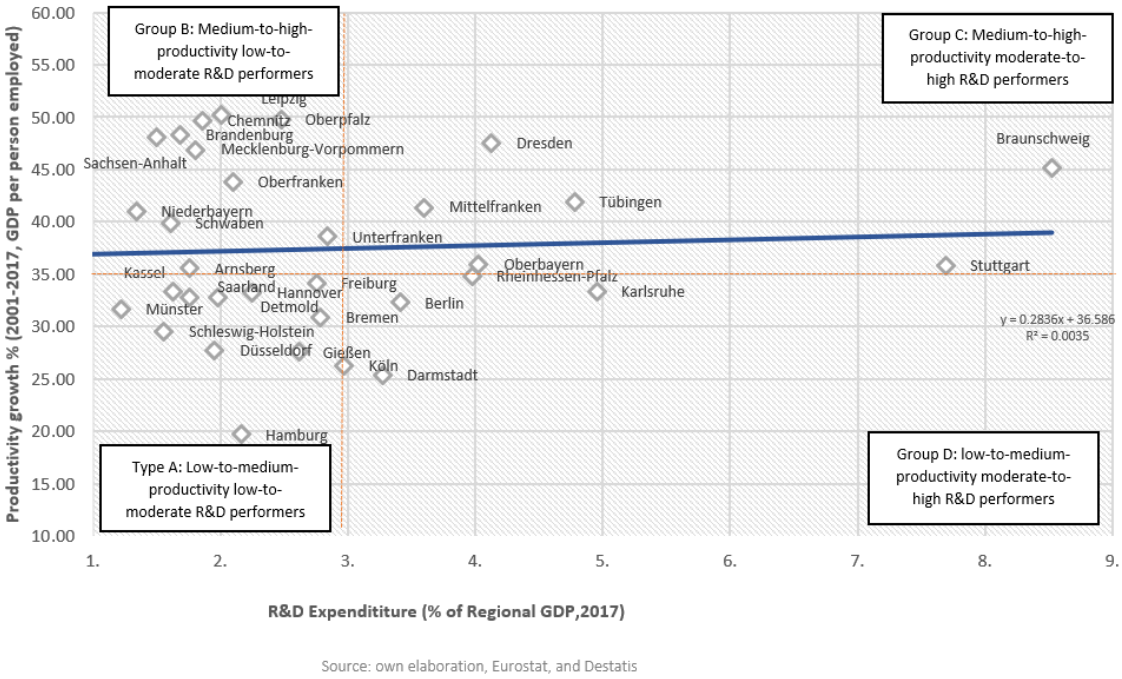
total factor strategy (i.e., data envelop analysis - DEA) to measure the efficiency of regional innovation systems in Europe (see, also, Chen and Guan, 2012).

Although each identification strategy has strengths and weaknesses, ideally, all four strategies need to be used (especially when regional data are available) in the process of identifying the extent to which the innovation-productivity paradox holds at the subnational level. To illustrate the value of a multi-identification strategy approach over a single-identification strategy, the remainder of this section utilises the NFS and BSS strategies in the context of 38 German statistical regions (NUTS II). The underlying aim is not to provide an advanced, sophisticated analysis of the relationship between innovation and regional productivity in Germany, but rather to demonstrate the importance of utilising different strategies when seeking to empirically pinpoint the extent to which the innovation-productivity paradox exists at the regional level.

Figure 2 plots the relevant data for regional R&D expenditure and labour productivity growth for 38 German regions (NUTSII) using Eurostat and the German statistical service (Destatis). Overall, and as illustrated by the blue linear regression line, the relationship between regional R&D expenditure and regional labour productivity is slightly positive in German regions, meaning that the innovation-productivity paradox is, on average, not empirically evident in German regions. Only a few regions exhibit an innovation-productivity paradox, particularly regions belonging in Group A (e.g., Hamburg, Düsseldorf, Giessen, Hannover) and a very few regions in Group D (e.g., Berlin, Darmstadt, Cologne and Karlsruhe). However, as shown in Figure 2, the relationship between regional innovation performance and regional productivity turns negative once regional innovation performance is measured broadly by, for instance, using data from the European regional innovation scoreboard[8] (European Commission, 2019). Surprisingly, and in contrast with Figure 2 whereby the R&D intensity of Germany appears to be concentrated in a few high-performing regions (e.g., regions of Braunschweig, Stuttgart, and Karlsruhe), **Error! Reference source not found.** shows that the innovative potential of the German innovation system is more evenly distributed across regions (see, also, Fritsch and Wyrwich, 2021a; Fritsch and Wyrwich, 2021b). It also implies that there is a larger number of regions (e.g., Group C) exhibiting innovation-productivity anomalies, with the most notable being the metropolitan regions of Berlin, Hamburg and Cologne.

[8] For a critical discussion on the methodology of the European innovation scoreboard, see Schibany and Streicher (2008) and Edquist et al. (2018).

Figure 2. R&D and productivity growth in 38 German regions (NUTS2)



Source: own elaboration, Eurostat, and Destatis

Source: Author's elaboration based on European Commission (2019) and Destatis data.

A 'paradoxical menu' for differentiated regional policy action in the post-COVID-19 era

This section brings the paper to an end. It begins by summarising the policy implications that were raised in various sections of this paper before examining three basic scenarios regarding the future of the innovation-productivity paradox in the post-COVID-19 recovery phase.

A 'paradoxical menu' of policy action

By using a typology of innovation paradoxes research, the paper identified four main types of regional policy implications. These are ***regional validity implications***, ***regional research base implications***, ***regional economic base implications*** and ***regional innovation system*** implications. Figure 3 summarises the policy implications that derive from the analysis in this paper. Based on the figure in question, there are three possible paths of regional policy action. The first path (i.e., Option 1) suggests that, once an innovation-productivity paradox has been identified empirically, one can search for causes, and thus also for remedies, in the regional research base. The second path of action (i.e., Option 2) locates the underlying causes in the regional economic base; whereas the last path (i.e., Option 3) seeks causes and remedies in the structure and functioning of regional systems of innovation.

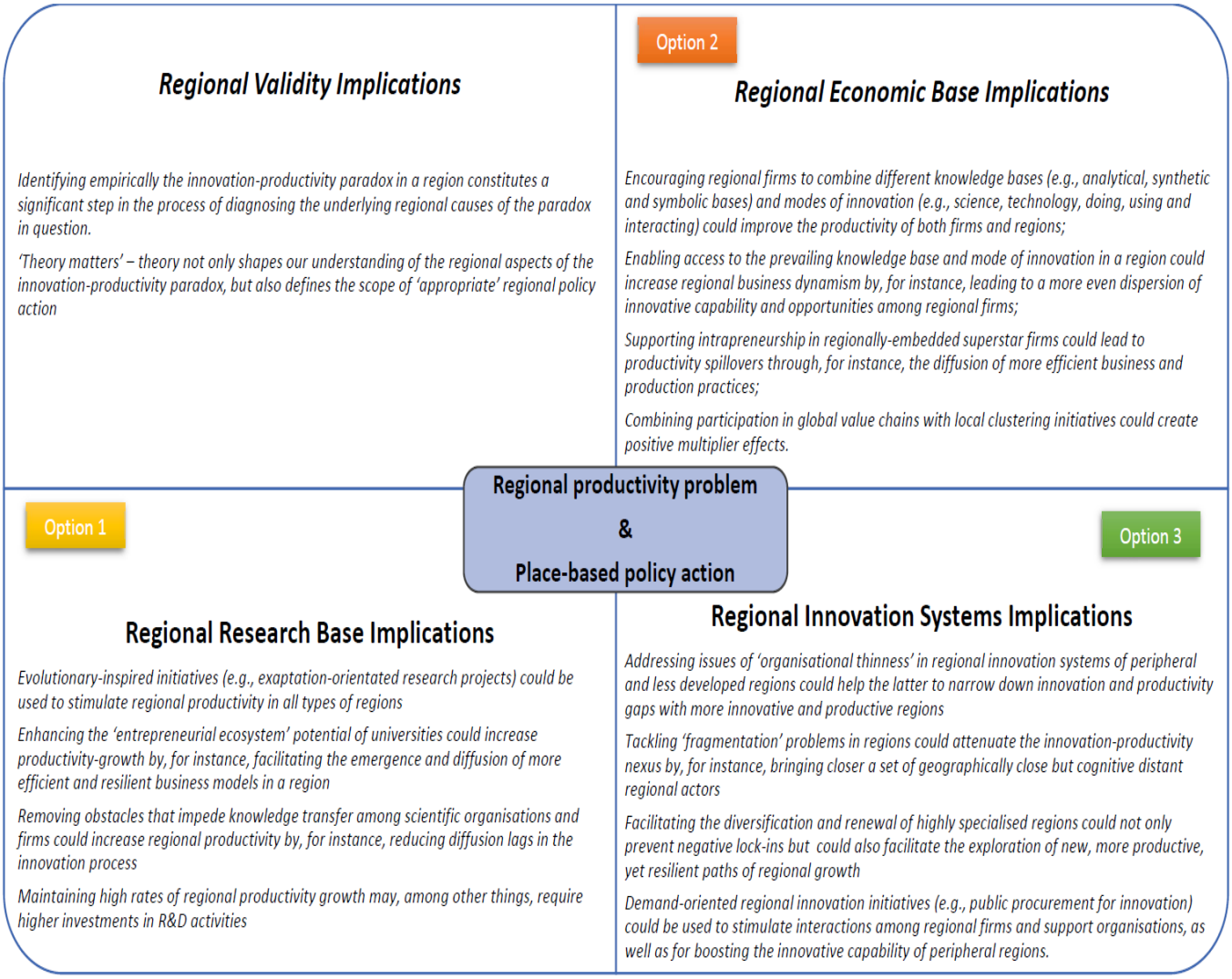
Which option is the most likely to address productivity issues in different types of regions? The short answer is that the nature of the productivity problem in each region – in brief, the ***regional productivity problem*** – will determine the answer to this question. In some regions (e.g., advanced, research-intensive regions), the regional productivity problem consists of maintaining the existing productivity-growth rates, whereas in other regions (e.g., intermediate and less developed regions), it concerns the question of declining

productivity growth, while in other regions, it is the question of narrowing down productivity gaps and creating 'decent jobs' that defines what the regional productivity problem is about.

One of the central messages of the Smart Specialisation policy framework is that regional context matters when it comes to regional policy action (McCann and Ortega-Argiles, 2013; Foray, Morgan and Radosevic, 2018); in short, what works in one place does not necessarily work in another place. The policy implications that derive from this paper confirm, among other things, that regional policy initiatives aimed at addressing the regional productivity problem are more likely to be effective when they are grounded in a sophisticated, evidence-based understanding of the regional context. In fact, 'no policy action at all' might be a better option than policy initiatives grounded either/both in 'popular beliefs' or/and a 'one-size-fits all' rationale. One must remember that the history of economic policy is replete with examples where both 'prevalent beliefs' and 'best practices' policies unintentionally did more harm than good[9].

[9] Edquist (2011), for instance, refers to a policy initiative that was introduced in the 1980s by the Swedish government. Inspired by the success of Japanese firms in the 1980s (Freeman, 1987), the initiative sought to increase the innovative capability and productivity of Swedish engineering firms by facilitating the development of process innovation rather than product innovation. The irony is that the Swedish engineering industry performed better in process innovation than any other country at the time (Edquist and Jacobsson, 1988). In other words, the programme should have targeted product innovation rather than process innovation. This example illustrates that, in the absence of analysis identifying a concrete policy problem, innovation policy may not only have little impact, but it can also waste valuable resources.

Figure 3. Regional policy implications: A "paradoxical menu"



Source: Author's elaborations.

Innovation and regional productivity in pandemic times

Initially identified in Wuhan city in China, the corona-virus disease (COVID-19) has, since the early 2020s, been shaking the socio-economic foundations of the 21st-century global economic system. Economic recession, rising health and housing costs, record levels of unemployment, rising income inequality are all widespread phenomena across the OECD member states (OECD, 2020; Ascani, Faggian and Montresor, 2021). Nevertheless, the long-term solution to such a humanitarian challenge relies upon the entrepreneurial act of innovation – in this case, the rapid development and diffusion of an effective, yet safe, vaccine against both COVID-19 and its mutations.

In light of the above, the paper ends by discussing three main scenarios of how the innovation-productivity paradox might evolve at the regional level in the post-COVID-19 recovery phase. The proposed scenarios do not seek to predict with accuracy what will happen; instead, they seek to enhance our understanding of what might happen once certain conditions are obtained.

- *1st scenario* – ***pervasiveness***. Undoubtedly, the pandemic has accelerated the deployment of digital and artificially intelligent technologies at work, including the associated need for the development and adoption of new business and work models (McKinsey, 2020; Chesbrough, 2020). However, since the productivity impact of investments in new technologies is often associated with a significant time lag (David, 1990; Freeman and Louçã, 2001), sluggish or declining productivity growth might be the 'new normal' in the recovery phase across most OECD regions.
- *2nd scenario* – ***resolution***. There is a widespread belief among the global business community that the pandemic has accelerated the pace of digital transformation in OECD economies (OECD, 2019a; McKinsey, 2020). At the same time, one of the key managerial implications that emanates from the COVID-19 pandemic is that collaboration among firms, and a more comprehensive array of organisations, is no longer an option but, is indeed, necessary for rapid innovation development (Chesbrough, 2020). By bringing together a set of cognitively different actors, the recovery phase could accelerate the fusion of promising technologies, creating new skills and capabilities which were lacking before the pandemic. This could shorten diffusion lags and boost productivity growth across firms and regions; thus, leading to the gradual resolution of the innovation-productivity paradox in the OCED economies.
- *3rd scenario* – ***no significant change***. This scenario refers to the possibility that the post-COVID-19 recovery phase may have no significant impact on regional productivity. Investments in digital technologies could reinforce existing productive and innovative capabilities of firms and sectors, and thus also existing paths of regional competitiveness, growth and resilience (Boschma, 2004; Simmie and Martin, 2010; Faggian, 2021). In this regard, the recovery process will reflect the economic forces and pathologies that were prevalent before the advent of the pandemic.

Regardless of which scenario will prevail (hopefully the second one), the challenges that regions are currently facing demand the development of a new generation of regional policies capable of addressing the root cause of several worrying pre- and post-COVID-19 developments (Kuhlmann and Rip, 2018; Faggian, 2021; Tsvetkova and Vermeulen, 2021). Such policies need to ensure that post-pandemic growth is not only innovation-led, employment-boosting and environmentally sustainable, but also socially inclusive and resilient to shocks. The existence of persistently high and rising income inequality, environmental degradation, and declining productivity rates during one of the most innovative and affluent periods in the history of the modern economic system demonstrate, among others things, that prolonged economic growth cannot, on its own, address economic and societal challenges through the 'invisible hand' of markets. It is the task of the 21st-century policy makers to make the 'invisible hand' of global markets 'visible' and beneficial to all places. Otherwise, "*the revenge of places that do not matter*" (Rodríguez-Pose, 2018) may simply be marking the beginning of the end, namely the end of global capitalism (as we know it).

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