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Evidence Review

Innovation and Productivity: Towards a Research and Policy Agenda

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About PIN

The Productivity Insights Network was established in January 2018 and is funded by the Economic and Social Research Council. As a multi-disciplinary network of social science researchers engaged with public, private, and third sector partners, our aim is to change the tone of the productivity debate in theory and practice. It is led by the University of Sheffield, with co-investigators at Cambridge Econometrics, Cardiff University, Durham University, Glasgow Caledonian University, SQW, University of Cambridge, University of Essex, University of Glasgow and the University of Leeds. The support of the funder is acknowledged. The views expressed in this report are those of the author and do not necessarily represent those of the funders.

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1. Introduction

In recent years, significant progress has been made to examine and substantiate the link between innovation and productivity at a number of levels and within a range of contexts and environments. However, there remain some core outstanding questions relating to our understanding of the factors within a firm's environment that encourage or discourage innovative activity, as well as the extent to which aggregate productivity is influenced by the innovative activities of individual firms (Hall, 2011; Atkinson, 2013). These knowledge gaps hint at issues relating to context, and the institutional and cultural frameworks within which innovation is promoted and executed. The aim of this paper, therefore, is to give some further consideration to these gaps by cutting into the innovation-productivity debate at a number of key theoretical levels in order to tease out elements for future research and policy agendas. It broadly focuses on theoretical and policy areas concerning the (inter-)organisational and spatial environment and context within which innovation occurs, with a particular emphasis on emerging institutional and behavioural theories of innovation and productivity. Also, whilst acknowledging the role of the firm as the primary unit for observing and examining innovation, the paper suggests that future research and policy should give further consideration to the role of particular human agents as key units for observing innovation-productivity processes.

To begin with, it useful to briefly consider the innovation-productivity debate from an historical perspective. As far back as the late eighteenth century, Adam Smith recognised the economic contribution of innovation, and the knowledge upon which it is based, through the division of labour. Smith observed increases in productivity arising from divisions of labour in the following three ways: (1) the increased dexterity of each worker (2) the saving of time lost in a shift from one task to another, and (3) the invention of higher-productivity machines and equipment. Of the three sources, the first refers to the formation of skills embodied in each worker. The third points to technical progress embodied in machinery and equipment as a result of advances in engineering at that time. In addition, the division of labour itself represents a new way of organizing the work process. All these sources arose from the knowledge bases of those individuals and organizations that introduced and implemented particular innovations (Huggins and Izushi, 2007).

Following Smith's observation that a variety of sources contribute to productivity growth, a number of economists – such as Karl Marx, Walt Rostow, and Simon Kuznets, to name a few - argued that structural changes driven by technological and organisational innovations are a source of growth (von Tunzelmann, 1995). The most well-known architect of such a vision is Joseph Schumpeter, who coined the evolution of a capitalist economy as 'creative destruction'. Schumpeter says: Capitalism … is by nature a form or method of economic change and not only never is but never can be stationary…. The fundamental impulse that sets and keeps the capitalist engine in motion comes from the new consumers' goods, the new methods of production or transportation, the new markets, the new forms of industrial organization that capitalist enterprise creates (Schumpeter, 1942). However, innovation was largely relegated to the background of mainstream economics for the greater part of the twentieth century (Huggins and Izushi, 2007). The efforts of neoclassical economists were primarily aimed at accounting for the allocation of scarce resources across alternative uses (Acemoglu et al., 2013). This focus excluded from their analytical framework the question of how firms choose and develop technologies, processes, and products.

In general, factors causing a change in technology were considered to be external to growth frameworks (i.e. 'exogenous'), while a change in labour and capital was seen as internal ('endogenous') and to be accounted for. For instance, Robert Solow found that over 80% percent of labour productivity growth in the US in the first half of the twentieth century was due

to something other than investment in plants and equipment. Solow (1957) called this the 'residual' and suggested that it included the effects of technical change. However, he did not account for how the technical change occurred, seeing it as residing outside his analytical framework. Growth accounting with this neoclassical view ensued, including the studies of Edward Denison in the 1960s and John Kendrick in the 1970s (Denison, 1962; Kendrick, 1976) Like their predecessor, however, they did not come to terms with issues relating to the means by which firms make investment decisions to create technological knowledge through research and development (R&D). It was not until the mid 1980s that this changed with the appearance of new growth theory. New growth theory attempted to 'endogenise' technical progress in a neoclassical framework. Given the dominance of the neoclassical paradigm in Anglo-Saxon countries (particularly the US), the birth of new growth theory, led by the Stanford economist Paul Romer (1986; 1990), caused a sensation in academic circles and beyond. It is new growth theory that sheds new light upon innovation-based productivity and economic growth.

Building upon these developments, the remainder of this paper aims to take a closer examination of these theoretical debates in order to identify the further questions they raise, as well as new and emerging areas for inquiry. Section 2 focuses on examining the role of knowledge flows for stimulating innovation, while section gives consideration to the function of entrepreneurs within these processes. Section 4 examines how both formal and informal incentives and disincentives – in the form of underlying institutions - may impact upon innovation and productivity performance. Allied to institutional explanations are more emergent behavioural theories of innovation, relating to underlying cultural, psychological and agentic factors, and these are explored in section 5. In section 6 there is an explicit focus on spatial dimensions, in particular the unevenness of innovation across sub-national regions, while section 7 assesses issues concerning the measurement and definition of innovation. Finally, section 8 provides some general conclusions and a summation of the key ground covered.

2. Knowledge Diffusion, Spillovers and Innovation Systems

Following Romer (1986; 1990), the sources of productivity growth – as well as economic growth more generally - are increasingly considered to be based on the role that the production, distribution and use of knowledge play in creating innovations within and across economies (Grossman and Helpman, 1994; Harris, 2001; Antonelli et al., 2011). In essence, the knowledge-based economy is generally considered to consist of the sphere and nexus of activities and resources centered on, and geared toward, innovation (Romer, 2007). The innovation systems literature, in particular, begins to suggest the role of knowledge flows across organizations as a (partial) solution to conundrums relating to the association between innovation activity and productivity performance (Freeman, 1987, 1994; Lundvall, 1995; Harris, 2011). Similarly, endogenous growth theory further stresses the role of knowledge as a key driver of productivity and economic growth, which departs from the traditional emphasis on the accumulation of physical capital (Lucas, 1988; Romer, 1986, 1990; Aghion and Howitt, 1998).

More specifically, theorists of economic development have increasingly drawn upon models of endogenous growth to better understand the factors underpinning such development. Within such theorising, knowledge diffusion and innovation systems are acknowledged as a vital component for improving productivity and economic development, with clusters being a key focus of contemporary economic theory and policy (Huggins and Izushi, 2007). The underlying tenet is that productivity is determined by the strength of key concentrations of specific industries and the knowledge spillovers they generate. Although considerable research has been undertaken, the black box of how clusters operate has not been opened to any great extent, and the long-term nature of agglomeration and innovation in terms of the lifecycles of innovative

places is an avenue rich in possibility (Carlino and Kerr, 2014). Similarly, open innovation practices – which are further discussed below - are advocated as an important source of productivity gains, but the evidence to support this is patchy.

It is suggested that perhaps the most interesting implications of endogenous growth theory relate to the impact of the spatial organisation of regions on flows of knowledge (Huggins and Thompson, 2014). In particular, it is considered that differences in regional growth can potentially be explained by differences in the conditions for creating, accumulating and – crucially - transmitting knowledge (Roberts and Setterfield, 2010). For instance, it is argued that increasing returns are realised through both the geographic and organisational processes resulting from localisation, and in time the spatial and economic diffusion of knowledge (Pred and Hagerstrand 1967; Storper, 2009).

Prior to the focus on endogenous modes of growth, the analysis of economic growth and long-term differences can generally be traced to the neoclassical approaches associated with Borts and Stein (1964), and more seminally Marshall (1890), which eventually led to a new emphasis on the role of increasing returns as proposed by Kaldor (1970) and others (Roberts and Setterfield, 2010). In these models, knowledge is usually considered to be a public good that frequently 'spills over' to other organizations, allowing others to reap where they have not necessarily sown (Acs et al., 2009). In endogenous growth models, knowledge is also considered to spillover to other organisations, resulting in the generation of increasing returns (Roberts and Setterfield, 2010), but in this case knowledge is not in fact considered to be a purely public good, but one that is at least partially excludable - such as through the use of intellectual rights - given that organisations often consider there to be incentives for investing in its creation. Similarly, models seeking to explain innovation outputs, such as patents, are based on a knowledge production function in which organisations (i.e. firms) intentionally pursue new economic knowledge as a means of generating innovation (Griliches, 1979; Audretsch, 2000). This pursuit is generally considered to consist of the appropriation and exploitation of the knowledge spilling over from other organisations (other firms, universities and the like).

Despite these theoretical developments, endogenous growth theorists throw little light on the mechanisms by which knowledge is transmitted across organisations, and ultimately generates the innovations that propel productivity gains. (Storper and Venables, 2004). This suggests a requirement for a research agenda that identifies the role that investments in spillover conduits make in generating productivity gains (Audretsch and Feldman, 1996). Knowledge spillovers can generally be defined as the continuum between pure knowledge spillovers that are uncharged, unintended and not mediated by any market mechanism, and rent spillovers consisting of externalities that are at least partially paid for (Andersson and Ejermo, 2005). Importantly, knowledge spillovers are increasingly conceptualised as a regional phenomenon, resulting in an enhanced focus on regions as key units through which economic growth can be best understood (Audretsch and Lehmann, 2005; O´hUallachain and Leslie, 2007). However, while organisations may benefit from local knowledge spillovers as an undirected and spontaneous 'buzz' (Storper and Venables, 2004), they may also need to consciously build non-local 'pipelines' to tap into knowledge from outside their region (Bathelt et al., 2004). This indicates a requirement to better understand the relationship between local and more spatially distant forms of knowledge flow, as well as the extent to which they impact upon innovation and productivity growth (Sorenson, 2017).

Innovation systems theory is useful in this respect, as it views an economy as an interlinked systemic network of components facilitating innovation (Freeman, 1987; Lundvall, 1992; Fagerberg, 2016). A key feature of the innovation system discourse has long concerned the role of both formal and informal networks of spatially proximate and co-located external

organisations, such as universities, R&D labs, and other firms or individuals, within the innovation process (Brown and Duguid, 2001; Cooke et al., 2004). It is often through the networks underpinning systemic innovation processes that firms access knowledge that they do not, or cannot, generate internally based on their own capabilities (Tomlinson, 2010; Bergenholtz and Waldstrøm, 2011). In this line, Audretsch and Lehmann (2005) refer to the role of entrepreneurs, who in their conceptualisation act as a knowledge filter addressing the gap between new knowledge and economic or commercialisable knowledge (Arrow, 1962).

3. Entrepreneurship and Open Innovation

The role of entrepreneurs as a knowledge filter is a key premise of the knowledge spillover theory of entrepreneurship, which argues that uncommercialised knowledge created in one organisation serves as the source of the knowledge that generates entrepreneurial opportunities and contributes to innovation and productivity growth (Audretsch and Lehmann 2005; Acs et al. 2013). This results in growth drawing upon the use of existing knowledge by both research and entrepreneurial labour to generate new knowledge and products at a rate determined by the institutions, policies and path-dependent factors present (Braunerhjelm et al. 2010). A key feature of this theory is the existence of the knowledge filter (Arrow 1962), which requires intentional and often complex efforts to access and assimilate (Audretsch and Lehmann 2005; Acs et al. 2013). A further premise of the theory is that knowledge access requires spatial proximity, with the localisation of knowledge suggesting that entrepreneurship will tend to be spatially located within close geographic proximity to the source producing such knowledge (Audretsch et al. 2006; Acs et al. 2013). The knowledge spillover theory of entrepreneurship is important for its role in developing an understanding of how entrepreneurial connections to knowledge sources promote innovation and productivity growth. However, it does not explore the nature and dynamics of the connections, and, as Hayter (2013) suggests, there is a need for research to dig deeper into examining these dynamics.

Highly productive economies are likely to be associated with efficient innovation systems and knowledge filters resulting from high levels of entrepreneurship, while weaker economies are those with failing innovation systems and low levels of entrepreneurship (Huggins et al., 2014). Innovation systems failure may occur due to the lack of coordinating and governance mechanisms underlying effective regional entrepreneurship and innovation-driven economies (Cooke 2004). In more entrepreneurial regions, network mechanisms are formed through the evolutionary interdependency emerging between entrepreneurs and other economic agents as a result of the recognition and necessity for knowledge- and innovation-based interactions beyond the market, with such mechanisms likely to be less apparent in entrepreneurially weak regions (Desrochers and Sautet 2004). However, a clear issue for future research and policy concerns the extent to which lagging economies can be renewed and transformed into ‘incubators of new ideas’ and provide opportunities for entrepreneurship to take place, as well as for discovering valuable innovations.

In recent years, the term ‘open innovation’ has been coined to define the networked nature of innovation mechanisms. According to Chesbrough (2003, p. xxiv), open innovation is ‘a paradigm that assumes that firms can and should use external ideas as well as internal ideas … as the firms look to advance their technology’. With its emphasis on ‘connect and develop’, the emerging paradigm of open innovation has provided important insights into the heightened role of knowledge accessing and networks in facilitating innovation and spurring the porosity of innovation processes (Dahlander and Gann 2010). Although existing evidence has mainly focused on open innovation in the context of large corporations, it is likely that it is a phenomenon equally applicable to a strata of more entrepreneurial firms (Laursen and Salter

2006; Perkmann and Walsh 2007). However, there is a paucity of relevant research to empirically support these claims, and it is no surprise that where studies have considered varying forms of innovation, there are differences in the extent to which open innovation practices appear to be effective. For example, in university-corporate interactions innovative outcomes tend to take the form of product rather than process innovation (Fritsch and Schwirten 1999).

From the above analysis it is clear that innovation no longer occurs in isolated laboratories, but through collaborative co-development networks between increasingly specialist producers, i.e. connected and collective agency. Innovation at all stages of the production process is a highly iterative and non-linear process. Learning happens through continuing interactions facilitated by social networks and open labour markets, which allows know-how and information to circulate freely. It is possible to contribute to the formation of such an ecosystem, but it cannot be easily planned from the top down, and once it gets started, the strength of such a system is that it fosters unanticipated re-combinations of skill and technology, and multiple, often parallel, experiments with technology, organisation, markets, and so forth (Saxenian and Sabel, 2008). In essence, this represents an example of the agency-system paradigm presented by some evolutionary economists (Dopfer et al., 2004; Dopfer and Potts, 2004). The challenge for future research and policy is to better consider how particular agents – be they entrepreneurs, policymakers, firms or other organisations – shape innovation systems that promote productivity gains, as well the way in which innovation systems themselves determine the composition and nature of agents of innovation within a particular economy.

4. Institutions and Innovation

Alongside the nature of innovation agents, there is a need to consider innovation institutions in the form of the incentives and constraints to creating and/or embracing new technology, as well as conventions in relation to the financing of innovation and norms regarding the 'restriction' or 'freedom' of ideas (Storper, 2013). For example, where innovative opportunity exploitation is encouraged through greater rewards (e.g. lower effective tax rates) or at the very least are not discouraged (as might be the case where high administrative burdens are present), the marginal latent innovator is more likely to pursue innovation opportunities (Baumol et al., 2009). Although conventions in relation to the financing of innovation, both R&D and 'softer' innovation, and incentives and constraints with regard to undertaking differing forms of innovation— e.g. radical, incremental, technological or social—are likely to stem from national and supra-national level institutions, more localised formal and informal institutions also play a role (Caragliu and Nijkamp, 2014; D'Agostino and Scarlato, 2015), and a significant study by Rodríguez-Pose and Di Cataldo (2015) strongly suggests that innovative capacity is related to the quality of institutions concerning the political governance of a region.

Similarly, effective institutions supportive of entrepreneurship are likely to make it possible for economic actors to take advantage of perceived opportunities to innovate (Boettke and Coyne, 2009). Institutions may direct individuals or organisations towards the adoption of similar entrepreneurial practices and structures to those currently prevailing in an economy, ensuring they gain support and legitimacy for their actions (Kibler et al., 2014). In general, it is clear that the type of entrepreneurial activity present in a locality may also be influenced by the quality of institutions present (Stenholm et al., 2013). Entrepreneurial institutions encompass a wide range of incentives, constraints and conventions, which Henrekson and Sanandaji (2011) summarise as including property rights, tax codes, social insurance systems, labour market legislation, competition policy, trade policies, capital market regulation, and the enforcement of contracts and law and order.

In the UK, the spatial unevenness of financial institutions across regions has been recognised as potentially a key impediment for innovation and productivity growth, with economically weaker regions being unable to improve their growth prospects (Hutton and Lee, 2012). At a national level, it has been found that places with better developed financial institutions and systems tend to grow and innovate faster (Demetriades and Law, 2006). However, the mere availability of finance is only found to aid growth up to a certain point, after which institutional constraints such as the weakening of the quality and effectiveness of financial intermediation take hold (Law and Singh, 2014). Furthermore, equity gaps across regions limit entrepreneurial and venture investment for innovation (Klagge and Martin, 2005). Capital markets do not function in a space-neutral way, and a highly centralised institutionalised system may well introduce spatial bias in the flows of capital to firms, leading to differing innovation trajectories across regions (Wójcik, 2009).

As Atkinson (2016) argues, a gap normally separates the production-possibility frontier, i.e. the innovations available to maximise productivity, and their use. For example, the McKinsey Global Institute (McKinsey, 2018) estimates that not all firms and industries in the United States have taken full advantage of ICT for productivity. Understanding the reasons for this gap remains a significant challenge for researchers and policymakers. This gap is likely to be due to the quality and efficiency of both formal and informal institutions, and although some work is emerging in this area, there is much to learn about the role of economic, political and social institutions in mediating the link between innovation and productivity.

5. Culture, Psychology and Human Agency

Parallel to new institutional understandings of the sources of innovation and productivity growth, contemporary economic development theory is moving toward a (re)turn to addressing the role of individual and collective behaviour in determining regional development outcomes (Huggins and Thompson, 2017). A number of concepts relating to the behaviour of individuals and groups of individuals have taken an increasingly central role in shaping an understanding of why some economies are better able to generate higher rates of development and growth, and avoid the low-road development trajectories and associated higher rates of inequality found in weaker economies (Tabellini, 2010; Tubadji, 2013). In particular, both personality and cultural traits are found to be a factor influencing rates of innovation, entrepreneurship and growth (Huggins and Thompson, 2016; Obschonka et al, 2015; Lee, 2016).

Individualism, diversity and more masculine cultures have been found to be associated with these outcomes, and a group of studies have found that open tolerant cities and regions grow faster reflecting the attraction of both conventional human capital and a greater presence of the creative class (Florida et al., 2008; Boschma and Fritsch, 2009). This allows access to more ideas, but can also help exploit the knowledge held and developed within a region as more diverse skillsets become available. Unlike cultural norms, which are formed at the group level, personality traits are based on the individual, and where an economy has a relatively larger proportion of particular types of personality present this is likely to affect innovation and growth. Using a cluster analysis approach, Rentfrow et al. (2013) identify three psychological profiles of regions - friendly and conventional, relaxed and creative, temperamental and uninhibited - covering the US states. They find that in terms of economic prosperity, a positive link exists with openness and extraversion, whilst conscientiousness displays a negative association.

These findings indicate that if we are to fully explore differences in innovation and productivity growth across economies, there is a need to understand how these differences stem from the

behaviour of human agents. From this psychological perspective it is instructive to draw on the Five-Factor Theory of Personality – the Big Five traits – to explain differences in behaviour across cities and regions, consisting of: (1) openness; (2) conscientiousness; (3) extraversion; (4) agreeableness; and (5) neuroticism (emotional stability) (Rentfrow et al. 2013). Alongside these personality psychologies, the concept of culture generally refers to the way in which people behave, often as a result of their background and group affiliation. Rather than concerning individual behaviour, culture relates to shared systems of meaning within and across ascribed and acquired social groups. Recent research has established a model of socio-spatial (or "community") culture whereby five component factors are argued to be of principal importance in the context of economic development, namely: (1) engagement with education and work; (2) social cohesion; (3) femininity and caring attitudes; (4) adherence to social rules; and (5) collective action (Huggins and Thompson, 2016). Emerging research has found both personality and cultural traits to be factors influencing rates of entrepreneurship, innovation, and economic growth across local economies within the UK (Huggins et al. 2018).

Human agents build and create institutions, and as Fagerberg (2016) states, the role of innovation policy in economic development has a lot to do with political will and resources, i.e., with human agency. For instance, experiments with proactive innovation policy in Sweden, Norway and Finland are examples of cases supported by (powerful) politicians, who saw this as a way to support important developmental goals'. Less is known about the role of such agents in larger economies such as the UK (Mazzucato, 2017), but it can be speculated that human agency is likely to be one of the key rooted drivers associated with more traditional explanatory causes of economic development, innovation and transformation, and should be considered seriously when addressing the routes available to mature economies in their bid to foster innovation, renewal and transformation.

More particularly, economies themselves produce a spatially bounded rationality that determines the forms and types of human agency apparent, and subsequently the nature of knowledge, innovation, and development (Huggins and Thompson, 2017). Innovation, entrepreneurship and creativity are social processes that involve groups of people who build off one another historically, and are the products of the places that act as the key organising unit for these activities, bringing together the necessary firms, talent and other institutions (Florida et al., 2017). Similarly, the symbiotic relationship between key agents and their location is found in research relating to the role of a limited number of "star" scientists in promoting the innovation performance of certain cities and regions (Zucker et al., 1998; Moretti, 2012).

Taken together, culture, personality and psychology form the psychocultural behaviour of an economy. These psychocultural behaviours have the potential to be persistent and deeply rooted in previously dominant economic activities, so that their influence is felt many decades later. For example, a historically high level of mining is found to be associated with lower entrepreneurial activity (Glaeser et al., 2015), positive attitudes to collective behaviour in the form of unionism (Holmes, 2006), and preferences against redistribution (Couttenier and Sangier, 2015). Therefore, in the context of mature economies in advanced nations such as the UK, there are strong reasons to suggest that the concentration of large-scale coal-based industries in these regions has left a lasting psychological imprint, with selective outmigration resulting in more optimistic and resilient individuals with positive and agentic mindsets seeking new environments that offer new economic opportunities, resulting in an indigenous population in the home region lacking in entrepreneurial spirit and innovative capabilities (Stuetzer et. al. 2016; Obschonka et al., 2017). Others suggest that these regions now suffer from a case of 'social haunting', whereby there is a kind of 'ghosted' affective atmosphere that has endured long after the traditional industries associated with these regions have disappeared (Gordon, 1997; Bright, 2016). In terms of the promotion of innovation and productivity growth, addressing

these embedded psychological, cultural and social factors is perhaps the most pressing challenge requiring attention by policy research and policymakers.

6. The Regional Innovation 'Paradox'

As a result of their deep-rooted problems, many economically weak regions have been in receipt of significant public funding targeted at fostering innovation and productivity gains. However, positive outcomes are rare, with evaluations often indicating little in the way of improved performance, although recent EU evidence points to some positive policy-induced regional innovation effects (Ferrara et al. 2018). The often-observed inability of these regions to effectively utilise the spending made available for innovation and entrepreneurship has been termed the regional innovation paradox, whereby it is argued that such regions lack the absorptive capacity in both the public and private sectors to make good use of such funding (Driver and Oughton, 2008). It is less clear why this paradox seems have become further entrenched in many regions even after significant and long-term policy intervention. The important task for research and public policy is to characterise accurately the 'interplay of causal factors in innovation expenditure', although 'identifying the nature of what is required (or how to intervene) is methodologically difficult' (Driver and Oughton, 2008). In particular, there is a paucity of evidence relating to how innovation expenditure should be balanced across a range of areas of activity.

Wales, for example, is a clear case-in-point of a region that appears to be suffering from such an innovation paradox. However, what is less clear is why this paradox seems have become exacerbated after more than 15 years of a devolved government that was installed precisely to equip Wales with higher rates of absorptive capacity. It has been suggested that another paradox is play here, whereby the introduction of regional government has itself stifled and hampered the capability of the regional economy to become more competitive through enhanced levels of innovation and entrepreneurship (Huggins and Pugh, 2015). A lack of local collective political agency in Wales, manifest in the form of political schisms and the like, may have resulted in unstable or less than coherent responses to particular development needs, as well as promoting the type of rent-seeking behaviour that results in negative development outcomes (Beer and Clower, 2014).

Political rent-seeking in this instance can be considered to consist of resources allocated by politicians and public officials, principally in terms of the time they give to certain activities to compete for the control of larger shares of public funds (Vasilev, 2013). Such rent-seeking is manifest in the form of resources that are used to maintain or further develop existing interests, to engage in policy and political turf wars, and more widely to enhance political capital. In general, the bigger the size of the public sector within an urban or regional economy, the more scope there is for rent-seeking activity that results in economic inefficiencies (Gelb, 1991). This can be especially harmful to innovation-related activities, which in turn hampers development (Murphy et al., 1993). Economies with a significant public sector wage premium and high public sector employment are significantly more likely to be engaged in government rent-seeking that results in inefficiencies through the non-productive activities occurring within public administration (Vasilev, 2013). Research has consistently suggested that the growth and bloating of the public sector can lead to increased economic inefficiency and wasted resources through rent-seeking behaviour (Persson and Tabellini, 2000; Vasilev, 2013). However, despite the known link between rent-seeking behaviour and productivity, less is known about the impact and role of innovation in this equation. Furthermore, whether or not devolved regions in the UK have experienced such a negative effect, which has subsequently impacted upon innovation potential and productivity, remains an unexplored area, but one which highlights the need to

further assess national and local governance arrangements, particularly in a post-Brexit environment.

7. Defining and Measuring Innovation Across Industries and Time

In recent years, the notion of innovation has been closely tied to the concept of the knowledge-based economy, which originally emerged out of the depths of the early 1980s recession in the US (Harris, 2001). By the end of the 1970s, the US economy had experienced a considerable slowdown in productivity growth. Whereas the labour productivity of US private business sector grew at an average annual rate of 3.5% between 1948 and 1965, its growth declined to 2.8% in the period between 1965 and 1972. After the first oil price shock, US labour productivity growth further fell to an annual rate of less than 1% and came to a virtual halt at the end of the 1970s (Baumol and McLennan, 1985). The productivity slowdown in the US was accompanied by deindustrialization, with widespread and systematic disinvestment in the country's basic productive capacity. Capital was diverted from productive investment in basic industries toward speculation, mergers and acquisitions, and foreign investment. This resulted in an ageing capital stock (such as equipment, machinery, and buildings) at home and a growth in the resources made available to US corporate subsidiaries operating abroad. As a consequence, plants were closed in basic industries such as steel and automotive, leaving workers displaced and communities abandoned (Bluestone and Harrison, 1982). The combination of the slowdown in productivity growth and deindustrialisation created doubts about service-led growth in the post-industrial era in the United States.

One factor that potentially explains this slower-than-expected growth, is the possibility of an increased difficulty in actually creating innovations. In the past, economists of the so-called 'acceleration school' considered that the generation of a new piece of knowledge would increase the probability of creating new products, processes, and ideas from novel and unanticipated combinations. In other words, the more knowledge is invented, the easier it becomes to invent still more. By contrast, the 'retardation school' of economics predicts the opposite; the more knowledge is invented, the less easy it becomes to invent still more (Machlup, 1962) If R&D activities are considered to be a main source of new knowledge useful to the production of goods and services, increased difficulties in creating new knowledge and innovations may be manifested by a decline of productivity in R&D, that is, the ratio of R&D output (i.e. new knowledge) to R&D input (e.g. professional labour) becomes smaller than before.

For measuring R&D output, the number of patents generated or registered is often used as a proxy.(Evenson, 1984) However, there are a number of potential pitfalls associated with equating the number of patents with the level of R&D output (Griliches, 1990). To start with, recent changes in the coverage of patent registrations makes historical analysis difficult (Cohen et al., 2000) In particular, a shift in the regime for the protection of intellectual property in computer software has led to a growth of software patents since the 1990s. Because of this, any historical analysis of changes in patent counts needs to take care when identifying a trend of growth or decline. Second, not all inventions are patented, as industries vary in their propensity to seek patents. Firms protect inventions with a range of mechanisms, including secrecy, lead-time advantages, and the use of complementary marketing and manufacturing capabilities.

Patent protection is particularly important in only a few industries, most notably pharmaceuticals (Cohen et al., 2000) Large R&D industries with significant governmental research support, such as automotive and aircraft, tend to patent very much less than their R&D inputs would predict. Furthermore, some low technology sectors, such as the manufacturers of screws, nuts, and bolts, take out occasional patents in spite of their almost non-existent R&D activities (Griliches,

1990). Patented inventions also vary greatly in the magnitude of their technical and economic significance. Granting patents to inventions means that these inventions qualify for the standard set by the patent office in terms of novelty and potential usefulness. While some patents prove extremely valuable, a large majority reflect minor improvements of little economic value. Moreover, many patents today are also defensive patents, aimed at blocking others' developments, rather than spurring innovation.

Although patents statistics are widely used as the best R&D-output proxy in terms of their quantity and accessibility, we need to take into account all the difficulties relating to their use and interpretation. If we take patenting as a proxy for outputs of inventive activity, long-run trends show a decline in the ratio of R&D outputs to inputs until relatively recently (Griliches, 1990). Faced with puzzling statistics on long-run trends, economists have offered a number of potential explanations. One is a decline in the propensity of firms to patent their inventions due to the increasing cost of obtaining and enforcing patents. However, this does not account for the universal observation of the drop in patent numbers relative to R&D workers. Another possibility is that the composition of industrial sectors has moved toward an increase in the activities of those sectors that are less likely to patent inventions (Connell and Probert, 2010). However, against this hypothesis, patenting relative to real R&D expenditures has fallen in all manufacturing sectors (Kortum, 1993).

A further possible explanation is a rise in the average quality of patents, which would require more R&D inputs per patent. Again, however, there is little evidence of universal changes in patent systems that would support this 'shrinking yardstick' explanation. This leaves the possibility that technological breakthroughs have become increasingly hard to find as knowledge frontiers continue to advance. In any narrowly defined field or product area, the pool of inventive possibilities may become depleted over time, until the field or product area is redefined anew by other major breakthroughs. As McKinsey (2018) argue, the multitude of possible answers to these complex questions mean that 'there is disagreement around the impact current technological innovation is having on the economy and what potential it has to once again boost productivity growth'.

8. Conclusions

This paper has sought to provide an introduction to some of the contemporary theoretical perspectives on innovation and productivity growth, and highlights a range of knowledge gaps relating to theories concerning endogenous growth processes, institutions, as well as behavioural theories relating to both cultural and psychological explanations. It is suggested that both behavioural and institutional-based conceptual frameworks can usefully complement existing theories of innovation and productivity growth. For example, although existing conceptual frameworks, such as the innovation systems literature, note the importance of entrepreneurship as a feature of such systems, it is not formally incorporated into these models. Indeed, even though the legacy and prevalence of a Schumpeterian discourse has led to 'entrepreneurship' and 'innovation' more often than not being uttered in the same breath, the connection between the two is usually implicitly, rather than explicitly, formulated.

It has also been suggested that theoretical perspectives on innovation and productivity/economic growth predominantly come in two related forms. First, those that seek to understand the processes and organisational factors relating to how innovation actually occurs, i.e. innovation theories. Second, a theoretical strand focused on understanding the role of innovation in facilitating economic growth and productivity improvement, i.e. innovation-based theories of economic growth. The conceptual frameworks employed by both theoretical

approaches broadly consist of either a resource-based view or an interaction-based view. The resource-based view largely concerns assets and endowments, and from the perspective of innovation theories relates to the types of industries, industrial mix and the capacity of these industries to foster innovation. From the innovation-based growth perspective, the focus is very much on the notion of endogenous growth and the accumulation of the forms of intangible capital associated with triggering and sustaining long-term economic growth.

Institutional-based frameworks allow us to consider how both informal and formal institutions are likely to moderate the behaviour of innovation actors through the underlying rules of the game, especially the constraints and incentives relating to innovation. Similarly, institutions form part of the broader growth systems and growth dynamics that ultimately determine productivity. Beyond this, behavioural factors encompassing culture, psychology and agency potentially provide new insights into the persistence of the long-term unevenness of innovation, growth and productivity. Behavioural patterns, and their evolution, provide a basis for understanding the type and nature of human agency, with such agency likely to be one of the key rooted drivers associated with more traditional explanatory causes underlying uneven rates of innovation and productivity.

In conclusion, it appears that to fully explore differences in innovation and productivity growth there is a need to understand how these differences stem from the behaviour of a range of human agents, and the extent to which this behaviour emerges from particular socio-spatial cultural traits and psychological traits. In other words, there are knowledge gaps relating to the role of cultural and psychological aspects in helping us understand why particular agents may possess a proclivity towards fostering innovation, as well as how the interactions between cultural and psychology factors result in behavioural systems with a higher or lower tendency to sustain long-term productivity growth.

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