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QUARTERLY REVIEW OF ACADEMIC LITERATURE ON THE ECONOMICS OF RESEARCH AND INNOVATION

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1. Digital technology diffusion- a matter of incentives, capabilities, or both?

Andrews, D., G. Nicoletti and C. Timiliotis (2018), "Digital technology diffusion: A matter of capabilities, incentives or both?", OECD Economics Department Working Papers, No. 1476, OECD Publishing, Paris. https://doi.org/10.1787/7c542c16-en

- Against the backdrop that the lack of digital technology diffusion may be "holding back" productivity growth, the authors look into how certain structural and policy factors impact firms' incentives and capabilities to adopt digital technologies.
- The paper introduces a novel data set to measure digital technology usage across 25 industries in 24 European countries and Turkey over 2010-2016.
- Overall, the results suggest that the adoption of digital technologies is influenced by the complementarity between intangible assets, and reinforced by adequate market environment conditions.

Concerns regarding the so-called "productivity paradox" have drawn significant attention in the recent literature. While on the one hand we see spectacular developments in Information and Communication Technologies (ICT) that shape the speed of innovation, on the other hand productivity growth stagnates. One explanation lies in insufficient digital technology diffusion across firms. Hence the paper analyses the underpinning structural and policy factors that could incentivise and increase firms' capabilities to adopt digital technologies. It introduces a novel data set covering 24 European countries and Turkey over 2010-2016. Information on *Digital technology usage* comes from Eurostat´s Community Innovation Survey (CIS) on "ICT usage and e-commerce in enterprises". Proxies for firms´*capabilities* (*organisational capital*, *skilled labour*, and *allocation of talent*) are based on World Economic Forum (WEF) and OECD survey-based indicators (PIAAC[1], OECD Science, Technology and Industry Scoreboard, and Adalet McGowan and Andrews (2015)), while *incentives* for digital technology adoption (*entry and competition*, and *exit and re-allocation*) are proxied by Eurostat indicators (venture capital investments as a % of GDP), OECD (OECD Product Market Regulation, OECD STI Scoreboard, OECD Indicators of Employment Protection, and OECD Insolvency Regime Indicator), and European Centre for International Political Economy. The empirical strategy follows Rajan and Zingales (1998)[2] to identify "the link between country-wide factors and adoption rates by relying on variability at the country-industry level". The authors focus on two key digital technologies - *cloud computing* and *back or front office integration*-, and control for *high-speed broadband internet* as an enabler of both. High quality broadband infrastructure/penetration is found "complementary to the adoption of digital applications". For *market incentives,* labour market flexibility, competition and access to risk finance all relate to the use and adoption of digital technologies. As for *firms' capabilities* for digital technology adoption, the paper finds that ICT competences, providing ICT training opportunities, and "an appropriate matching of workers' skills to jobs" are all important factors for adopting digital technologies.

[1] OECD Programme for the International Assessment of Adult Competencies (PIAAC)

[2] Rajan, R. and L. Zingales (1998), "Financial dependence and growth", American Economic Review, Vol. 88, pp.559-586.

2. Three frames for innovation policy: R&D, systems of innovation and transformative change

Schot, J., & Steinmueller, W. E. (2018). Three frames for innovation policy: R&D, systems of innovation and transformative change. Research Policy.

- Following a historical overview, the authors identify and explain the main frames shaping innovation policy throughout time.
- Specifically, the paper argues that a new frame of innovation policy should encompass prominently the Sustainable Development Goals (SDGs) and hence lead the path towards "transformative change".
- The authors conclude that all frames are insightful for policy-making but exploring new approaches for transformative innovation policy should become central to tackle the pressing environmental and social challenges of our era.

Overall, the paper provides a reflection on the different frames *for designing and implementing effective policy solutions for complex policy problems.* In addition, it assesses what this means for the current reality when pressing environmental and social challenges are threatening the sustainability of economic systems. The *first frame* has its focus on *innovation for growth, i.e.* how research and innovation can lead to economic prosperity including mass production and consumption. It is mostly associated with the post-World War II period when there were concerns of increases in inflation, unemployment and economic instability in general. Hence there was a consensus that the State should be more actively involved in funding research and scientific discoveries which would be complemented by applied R&D by the private sector. In parallel, work by Abravomitz (1956)[3] and Solow (1957)[4] reinforced the conviction that science and technology were beneficial to economic growth and that the process of technical change deserved more attention by the policymaker.

In terms of policy practices within the first frame, these include the definition and support of applied research *missions* for instance in the United States (defence, health, energy) and in France notably in atomic energy and medical research. The *second frame* of *national systems of innovation* relates to the 1980s in a period when globalisation, international trade competition and *the prospects of being left behind* were worrisome phenomena to some nations. At the same time, there had been a slowdown of the catching up process between high-income and low-income nations. As a result, the previous *linear model of innovation* was re-assessed. In fact, more importance was given to the concept of "absorptive capacity" of knowledge as well as to the *cumulative character of technological change.* Some examples of policy practices within this frame include building "technopoles" (e.g. in France) to strengthen the interactions for knowledge creation, transfer and commercialisation, and the revitalisation of certain areas with investments in *new technology-based firms* (e.g. Research Triangle in North Carolina). Finally, the *third frame-transformative change-* is still being explored with the goal of addressing the SDGs put forward by the United Nations (UN).

Hence transformative innovation policy has the ambition to more vigorously channel research and innovation towards scientific and innovative breakthroughs that will address climate change, rising inequality, etc, while at the same time enabling prosperous societies. Mission-oriented policies with those goals in mind are an example of that transformational thinking which mobilizes all the stakeholders in the system.

[3] Abramovitz, M. (1956). Resource and output trends in the United States since 1870. In Resource and output trends in the United States since 1870 (pp. 1-23). NBER.

[4] Solow, R. M. (1957). Technical change and the aggregate production function. The review of Economics and Statistics, 39(3), 312-320.

3. Mobilizing innovation for sustainability transitions: A comment on transformative innovation policy

Fagerberg, J. (2018). Mobilizing innovation for sustainability transitions: A comment on transformative innovation policy. Research Policy.

- The author provides an overview of the evolution of policy approaches towards innovation throughout time.
- The paper argues that a new approach to innovation policy is needed in order to enable and accelerate the transition to sustainability- *transformative innovation policy*.
- The paper concludes with recommendations on how to promote an ambitious agenda for transformative policies.

This paper is actually a comment on the previous one (number 2 in this review). Long-term forces such as climate change are increasingly threatening the sustainability of the planet. As a result, innovation (policy) is required to mitigate the devastating consequences of climate change including the rise in global temperatures and its impact on the environment. The paper reinforces the idea that *innovation is essential for the transition to sustainability.* The author explains that the role of innovation has changed throughout time. Indeed, Schumpeter was one of the pioneers in this by putting forward a theory of *innovation as the driving force for long run economic and societal change.* Moreover, with his theory of innovation on "new combinations" Schumpeter "opened the door" for a more holistic view on innovation which considered that innovation is also about how you combine the different resources (labour, capital) to create something new. It also depends on supply and demand factors. The author then mentions that the promotion of "radical innovations" has been targeted under "mission-oriented" policies in certain "niches" in the United States by military, space and health agencies expecting significant economic and societal impacts from such public interventions.

The paper also discusses the changing technological regimes. According to Winter (1984)[5], *large firms in established sectors are analysed as highly efficient but rather inert organisations working under a common umbrella, a "technical regime".* However, some authors have more recently revised this concept to account for the importance of sustainability, considering that, instead, there should be a "multi-level" approach that reflects i) a macro-level with conditions that evolve slowly and exogenously; ii) a meso-level which corresponds to a "sociotechnical" regime, and iii) a micro-level which relates to the space for experimentation of radical innovations in certain niches. "Transition action plans" are also being experimented by policy-makers where a vision towards sustainability is discussed involving a wide range of stakeholders. In addition, the paper also discusses the adaptation to technological revolutions. According to Christopher Freeman and Carlota Perez, "*a number of complementary factors need to be in place, not only in the form of an appropriate infrastructure but also with respect to the economic, organisational and institutional setup of the society".* To conclude, the author presents five different recommendations to take transformative innovation policy to the next level: i) Set the direction by mobilising the different assets in an open and transparent way around that vision; ii) Embrace the opportunities brought by new disruptive technologies to the benefit of sustainability; iii) Mobilise the private sector and stimulate their involvement towards sustainable goals; iv) Move towards a holistic approach for policy-making which duly combines the different factors shaping innovation; v) Improve the governance level towards more effective coordination and policy alignment around strategic objectives for sustainability.

5 Winter, S. G. (1984). Schumpeterian competition in alternative technological regimes. Journal of Economic Behavior & Organization, 5(3-4), 287-320.

4. Towards system oriented innovation policy evaluation? Evidence from EU28 member states

Borrás, S., & Laatsit, M. (2018). Towards system oriented innovation policy evaluation? Evidence from EU28 member states. Research Policy.

- The aim of this paper is to assess whether innovation policy evaluation has evolved towards a system-oriented approach.
- The move towards system-oriented innovation policy evaluation is analysed based on a review of the policy practices of all EU Member States.
- The authors conclude that only a few countries have actually moved towards a system concept, and that this "*limited systemic approach in evaluation*" diminishes the potential for policy learning.

The complexity of innovation means that increasingly policy makers need more intelligence for developing innovation policy. Hence *foresight, technology assessment and innovation policy evaluation* are increasingly relevant for policy learning and advice. The paper focuses on this last dimension: whether system-oriented innovation policy evaluation is gaining momentum in the European Union. The authors define this approach as *the regular and knowledge-based set of practices that evaluates the effects of innovation policy within the innovation system.* The model defines four main attributes of system-oriented innovation policy evaluation: i) "coverage", i.e. whether the key elements are being evaluated which refers to *innovation policy instruments, innovation policy mixes, and socio-economic performance assessments;* ii) "systemic perspective", i.e. whether institutional features and the socio-economic dimension are accounted for; iii) "temporality", meaning the regularity with which countries undertake policy evaluations; and iv) "expertise", here referring to the *knowledge-based nature of evaluation practices.*

The process of building the dataset involved a set of different steps. First of all, semi-structured interviews in all EU Member States were conducted with governmental experts and researchers. Secondly, the paper took into consideration relevant documents on each country´s evaluation practices mostly from the Research and Innovation Observatory (RIO) database[6] and the Science and Innovation Policy Evaluation Repository (SIPER) database[7]. The final dataset was hence composed by merging both approaches. As for the methodology, essentially it involved the attribution of scores of 0, 1 or 2 *according to the intensity of the data.*

The results show that Austria, Finland, Germany, Ireland, the Netherlands and Sweden are the EU Member States that *have developed comprehensive practices* in this regard. At the bottom of making use of system-oriented innovation policy evaluation are Croatia, Cyprus, Greece, Italy, Malta, Luxembourg, Romania and Slovakia where evaluation practices seem to be quite rare and specific, or even non-existent.

[6] https://rio.jrc.ec.europa.eu/en/country-analysis

[7] http://si-per.eu/

5. The Impact of Artificial Intelligence on Innovation

Cockburn, Iain M., Henderson, R., Stern, S. (2018). The Impact of Artificial Intelligence on Innovation. National Bureau of Economic Research Working Paper Series*,* Working Paper 24449.

- The paper investigates whether Artificial Intelligence (AI) may serve as a new general-purpose method of invention that could reshape the nature of innovation processes and the organisation of R&D.
- Measuring publication of papers and patents within the three main technology areas of AI shows different patterns of deployment.
- Artificial Intelligence-based deep learning may be able to support substantially discoveries across many domains where classification and prediction tasks play an important role.
- Findings suggest that further development in this area may have impacts on the management and organisation of innovation, as well as on innovation and competition policies.

Although the origins of Artificial Intelligence (AI) in the field of computer science and its early commercial applications have been in relatively narrow domains, the learning algorithms recently developed suggest that AI may have applications across a very wide range of fields. Such an expansion into wide domains of applications could make AI a general-purpose technology with the potential to enhance significantly productivity and quality across a number of sectors. This could improve productivity within the research sector and further broad (commercial) deployment could have profound impacts on economic growth as well as on society in general.

The authors identified and classified publications and patents falling into three main areas of AI: robotics, symbolic systems and deep learning. The key empirical evidence aimed to answer whether in the late 2000s deep learning shifted more towards "application-oriented" research than either robotics or symbolic system.

The findings confirmed that learning-oriented AI may represent a general-purpose technology that is now beginning to be exploited far more systematically across a wide range of applications. Nevertheless, it is too early to look for evidence of knowledge spillovers between innovation and the general-purpose technologies. These findings allowed the authors to think about larger impact of the technology on economy-wide innovation, growth and productivity. The rise of general-purpose predictive analytics using large datasets seems likely to result in a substitution towards capital and away from labour in the research production process. Bearing this shift in mind, policy makers should consider issues of availability of relevant data for further dissemination or the gap between the private and social incentives to share and aggregate data. Among the immediate potential policy implications, ownership of data, patent systems, consumer protection or competition policy rank high in the list.

6. Global Production Networks, Foreign Direct Investment, and Supplier Linkages in the Integrated Peripheries of the Automotive Industry

Petr Pavlínek (2018) Global Production Networks, Foreign Direct Investment, and Supplier Linkages in the Integrated Peripheries of the Automotive Industry, *Economic Geography*, 94:2, 141-165.

- The paper provides insights into the regional development effects of Foreign Direct Investment of the automotive industry in Slovakia
- It analyses the quantity and quality of supplier linkages through a survey and interviews with automotive firms.
- The author remains negative about the benefits of supplier linkages between foreign subsidiaries and domestic firms, which undermine the potential for technology and knowledge transfer.

In order to analyse the regional effects of Foreign Direct Investment (FDI), the article looks at a group of less-developed economies, which have attracted investment to the automotive sector. It identifies the organisation of global production networks in the industry, while aiming to analyse the regional development effects of this network organisation. After an introduction and description of these regions, the study presents a typology of FDI linkages and examines the quality and quantity of these linkages in Slovakia.

These "peripheral regions" tend to capture only a low share of the value created because of, *inter allia,* high shares of low-wage assembly jobs, low shares of non-production and strategic functions. This has been confirmed to a large degree also in Slovakia, where the integration of domestic firms in the high-volume passenger car industry remained weak. The study further identified limited R&D activity of foreign subsidiaries, as well as low absorptive capacity among domestic firms as factors explaining weak linkages between international and domestic companies.

7. Cohesion Policy Incentives for Collaborative Industrial Research. The Evaluation of a Smart Specialisation Forerunner Programme

Crescenzi, R., de Blasio, G., & Giua, M. (2018). *Cohesion Policy Incentives for Collaborative Industrial Research. The Evaluation of a Smart Specialisation Forerunner Programme* (No. 0231). Spatial Economics Research Centre, LSE.

- The study evaluates the impact of the Collaborative Industrial Research (CIR) programme – considered as the precursor of the Smart Specialisation Strategy in Italy in the programming period 2007-2013 – on firms' investment, value added and employment.
- The CIR involved the Convergence regions in Italy, i.e. the Southern regions lagging behind the rest of the country, and provided €1 billion funding to local beneficiaries for innovation cooperative activities.
- Results suggest that the programme was overall unsuccessful in stimulating either investment, value added or employment.
- The collaborative dimension did not contribute to improving the outcome with the exception of partnerships with universities. Differently, some positive results are found for low-tech sectors.

The Smart Specialisation Strategy (S3) practices and procedures represent the evolution of the EU Innovation and Cohesion Policies and characterise the programming period 2014-2020. While there is still lack of evidence in order to evaluate the effectiveness of the new approach to regional innovation and development policy, the Collaborative Industrial Research (CIR) programme, implemented in Italy in the programming period 2007-2013 constitutes an "experimental" case for evaluation. The programme amounted to €1 billion and shared several similarities with S3, being focused on local demand for innovation in innovative smart sectors and oriented to stimulate firms-firms and firms-universities collaboration. The main difference with S3 concerns the absence of an entrepreneurial discovery process driven by a bottom-up diagnostic of needs and opportunities by stakeholders, being rather based on top-down priorities selection.

The authors consider that the CIR may be seen as the predecessor of S3, also given that the managing authority and the platform of the CIR are the same of S3. The study makes use of data about successful and unsuccessful applicants to the programmes, including information on the score of each application, and using the tax code of participating firm to merge the data with account sheet information taken from different sources such as CERVED, the National Institute for Social Security and patents from ORBIS. The overall database allows to evaluate the impact of the funding via CIR on investment, value added and employment, while accounting for firms and project characteristics via a Regression Discontinuity Design.

Findings reveal that participation to the programme failed to provide positive results, while a slight negative impact is found for Value Added creation. Concerning the characteristics of the programme, projects being characterised by collaboration among a large number of beneficiaries perform worse than average across all the three dimensions under explanation. A slight positive impact is found in those cases where a university is among the partners. Finally, the authors find positive results for investment and employment creation for beneficiaries belonging to low-tech sectors, indicating the need to make a broad diagnosis of the specificities of regional economies – e.g. considering upgrading of traditional industries – rather than a priori selection of high-knowledge intensive activities only.

8. Industrial diversification in Europe: The differentiated role of relatedness

Xiao, J., Boschma, R., & Andersson, M. (2018). Industrial diversification in Europe: The differentiated role of relatedness. *Economic Geography*, 1-36.

- The paper investigates the pattern of industrial diversification across 173 regions in Europe, analysing the role of industry relatedness – i.e. how close two industries are in terms of technological content and skills requirement – and innovation capacity in shaping the process.
- The evolution of the industry structure is found to be path dependent and the emergence of a new industry specialisation is positively associated with its relatedness to existing industries.
- The likelihood of the emergence of path breaking specialisation depends on the regional innovation capacity, which relaxes the influence of relatedness.

The decline of established industries and the emergence of new ones due to new technological opportunities has been the subject of extensive literature, especially due to the consequences in terms of prosperity for national and local economies. The latter geographical dimension is particularly relevant, since the effects of industry decline are more pronounced at the local level, as so is the high heterogeneity in the economic structure observed in European regions. Two types of industrial diversification are possible. Related diversification is the predominant one: evidence suggests that new technologies and industries are likely to emerge when related technologies (and industries) do already exist, revealing a path dependence process. Unrelated diversification is a rarer and path-breaking event since it requires the acquisition of new technological capabilities and higher uncertainty.

Using a sample of 173 European regional economies from 2004 to 2012, the study analyses the relationship between the local economic and industrial structure and industrial diversification, accounting for the role innovation capacity has in shaping the process. Regional economies are classified in three groups: i) knowledge hubs, characterised by the highest innovation and economic development; ii) industrial production zones, characterised by agglomeration but lagging behind the frontier; iii) non Science-Technology driven regions, mainly peripheral regions (i.e. South and East of Europe) with the lowest innovation performance.

Results confirm the role of relatedness (proxied by the density of similar industrial activities) in shaping the emergence of new specialisations in a regional economy. This finding has implications for the role of innovative capacity: the higher the innovation potential of the economy, the higher the likelihood of new industries to emerge and industrial diversification to increase. In addition, the relevance of relatedness decreases in regions with higher innovative capabilities, i.e. in knowledge-hubs and industrial zones, while remaining a predominating factor in Eastern and non S-T based economies. In other words, high innovation (absorption) capacity and a large knowledge endowment seem to be a prerequisite for disruptive innovation trajectories to emerge.

9. Smart specialisation, innovation policy and regional innovation systems: what about new path development in less innovative regions?

Asheim, B. T. (2018). Smart specialisation, innovation policy and regional innovation systems: what about new path development in less innovative regions?. Innovation: The European Journal of Social Science Research, 1-18.

- The paper builds a conceptual framework for regional innovation and development policies based on smart specialisation strategies and the regional innovation systems approaches. An application to the region of Mazovia (Poland) is provided.
- Smart Specialisation Strategies aim at the creation of a new path of development, which depends on the sectoral composition of the local economy, its absorptive capacity and the network across innovation actors.
- It is argued that an unrelated "path-breaking" specialisation can be achieved even by less developed and innovative regions, if policy and the bottom-up approach can mobilise the innovation actors to enable the applications of new technologies to existing activities.

The Smart Specialisation Strategy (S3) promoted by the European Union proposes a new framework to understand and promote innovation and growth at the regional level, acknowledging the key role of economic diversification. It is based on the joint undertaking of top-down and bottom-up policies, focusing on the shared responsibility of local actors in the regional innovation system – i.e. firms, entrepreneurs, public institutions, universities and research centres – to engage in a (self) discovery process given the regional specificities. An economy structure can evolve following two paths, i.e. diversifying into activities related to the pre-existing knowledge and production base, or into activities based on unrelated knowledge and technological opportunities.

The study argues that the unrelated diversification route is a valid policy option also for regions characterised by low absorption and innovation capacity and poorly diversified. Indeed, unrelated diversification is an option that allows poor regions to either upgrade their existing industry by i) scaling up their position into global value chains and/or ii) developing in a niche of the sector through the integration of specific knowledge. While being riskier in nature, a policy of this kind would generate the so called "long jumps" capable of generating new avenues for subsequent structural transformation. The authors apply the framework to Mazovia, the richest Polish region characterised by a strong dualism between Warsaw and the periphery and, as such, being only a moderate innovator according to the European Regional Innovation Scoreboard (2017). The periphery is characterised by a low-low profile, i.e. low innovative capacity and low diversified economic activity.

While at a first glance this would suggest an approach based on relatedness, the framework argues for an approach based on the application of unrelated Key Enabling Technologies – e.g. bio- and nano- technologies – to the existing agricultural base, in order to increase complexity, value added and productivity in the sector (e.g. moving from exports of raw food to food processing and quality upgrade). This can favour the scaling up within the value chain creating a virtuous process of path upgrading, while creating the conditions for the emerging of niche activities. In terms of policy implications, a S3 would contribute by mobilising the various actors in the innovation system to increase their cooperation, and by strengthening collaboration between industry, research centres and universities in the region, as a fundamental prerequisite to overcome the low absorption capacity of the business sector.

10. The Product Space Conditions the Development of Nations

Hidalgo, C. A., Klinger, B., Barabási, A. L., & Hausmann, R. (2007). The product space conditions the development of nations. Science, 317(5837), 482-487.

- This seminal paper provides an original contribution to understanding inequality in distribution of income and growth, by linking economic growth to the capability of a country to differentiate its economy.
- The capability to move to new products and activities is strongly determined by the relatedness between existing skills and knowledge and those required by the new products.
- By using network theory and historical data, the analysis reveals that economies specialised in activities at the core of the network easily move to higher share of products and sectors, due to the centrality of their knowledge and skill endowment.
- Poorer economies are those whose actual specialisation is at the periphery of the network and less related to the core. To scale up and catch up with the richest economies, a long jump would be required.

The fathers of development economics suggest that the export specialisation of a country strongly affects its economic performance, confirming Ricardo's original intuition. The lack of an adequate theoretical framework led standard mainstream economic theory to use either factors endowment or technological differences to incorporate this idea in the models. The contribution of the paper is to provide a theoretical framework to explain structural change and economic growth, overcoming the limitation of the two approaches.

In particular, the authors assume that different activities require different skills and knowledge and the ability of an economy to move from one product space to another depends on how close the new set of "skills" is to its current one. By using network analysis techniques, the authors show how the richest economies are those at the core of the network, therefore more capable to move from one sector to another. This is the case for instance for industrialised countries and, to a lesser and more specialised extent, for East Asian economies. Differently, Latin America and more notably Sub-Saharan economies export mainly products belonging to sectors at the periphery of the product space (network), which in turn offer fewer opportunities to move to different and more productive activities. Data also show that the historical trend has been characterised by high relatedness, e.g. economies, especially those at the periphery, have moved to the "closest" products in the network. In terms of economic growth and prosperity, this implies a bi-polar distribution of countries, with two main modes representing the richest and the poorest regions. Simulations suggest that, in order to fill this gap, poorer countries should be allowed to move from one product to another even if the degree of relatedness is low, an assumption unlikely to hold given their knowledge endowment and their absorption capacity.

As a main policy implication, the only way to fill the gap is to promote via policy "long jumps" that would allow underdeveloped economies to move from the periphery of the product space to the core, most notably by promoting the incorporation of new technological opportunities in the existing product space/economic structure. This is relevant in the context of the EU S3 and the policy approach it endorses.

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