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

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This issue focuses on the topic of policy evaluation in research and innovation. There is a particular emphasis on the issue of the policy mix as it is one of the most challenging in the evaluation literature. Furthermore, the review features a paper on behavioural additionality and papers on performance measurement and R&D inputs and outputs.

1. Policy evaluation in innovation and technology: an overview

Papaconstantinou, G. and Polt, W. (2007). Policy evaluation in innovation and technology: an overview, OECD, Paris. Available at: <http://www.oecd.org/sti/inno/1822393.pdf>

- An increasing trend towards more evaluations follows tight government budgets and rising allocative competition; results of evaluations start to be discussed more publicly and are entering higher levels of policy making.
- Since the emergence of programme evaluation, methodologies further evolved to capture a complex mix of methods, moving away from purely quantitative evaluation towards adopting a portfolio-approach.
- However, quantitative techniques need further development to also take into account “soft factors” of innovation that capture more informal behavioural aspects of change occurring at the level of the firm.

This review summarises the work of the OECD on best practice in innovation and technology policy evaluation. Albeit this summary paper was drafted more than a decade ago, the identified trends accelerated since then and evaluations are now entering higher levels of policy making in Europe. Economic and behavioural effects are analysed through their impact on firm and individual incentives so as to guide an efficient allocation of resources. Evaluations are used to find the most viable and promising direction for research and innovation policies. The emergence of programme evaluation followed the trend of a surge in subsidies in industrial innovation schemes that were assessed by in-depth surveys and quantitative techniques. Over the last decades, evaluation practices further evolved, away from quantitative project evaluation towards adopting a portfolio-approach. Rather than focusing on individual projects and an ex-ante evaluation, continuous monitoring is now the norm; also incorporating other alternative sources of information. The underlying economic theory of “market failure” type argument was complemented by improving our understanding of the processes within a complex innovation system aiming at the notion of “systemic failure”. On the firm level changing innovation behaviour and capturing a dynamic learning environment requires alternative methods. Quantitative techniques need further development to take into account “soft factors” of innovation, such as knowledge creation for example. Furthermore, an optimal institutional design of evaluations that is transposable onto other countries does not exist. In order to provide tailor-made solutions for specific countries, discussion that is more informal with respect to the design of policy evaluation is needed – also to guide change that is more radical or disruptive in innovation policy.

2. The state of applied econometrics: causality and policy evaluation

Athey, S., Imbens, G. W. (2017). The state of applied econometrics: causality and policy evaluation. *The Journal of Economic Perspectives*, 31 (2): 3-32.

- The paper summarises some of the most recent developments in the econometric toolbox for addressing causality issues in the context of estimating the impact of policies.
- In addition to presenting some novel identification strategies in programme evaluation, the authors stress the importance of combining these tools with supplementary analysis intended to assess the credibility of estimation and identification strategies.
- Finally, the paper shows how supervised machine learning techniques can improve the performance of causal analysis, particularly in cases with many covariates.

Due to financial, political, or ethical reasons, randomised controlled experiments cannot always be performed for drawing inferences about the effects of a policy. Therefore, in these cases, policy evaluation studies rely on observational data. Methods used to draw causal interference from observational data are called identification strategies. Some of the novel identification strategies, analysed in the paper, include regression discontinuity, synthetic control, external validity, and the causal interpretation of regression methods. Complementary to the identification strategies, different types of supplementary analyses, such as placebo analyses as well as sensitivity and robustness analyses, are designed to make the identification strategies more credible. Additionally, the authors show some implications of recent advances in machine learning methods for causal effects, including methods to adjust for differences between treated and control units in high-dimensional settings, and methods for identifying and estimating heterogeneous treatment effects. The authors argue that in addition to holding a great promise for improving the credibility of policy evaluation, machine learning methods can also be used to access supplementary analyses more systematically.

3. Characterizing the policy mix and its impact on eco-innovation: A patent analysis of energy-efficient technologies

Costantini, V., Crespi, F., & Palma, A. (2017). Characterizing the policy mix and its impact on eco-innovation: A patent analysis of energy-efficient technologies. *Research Policy*, 46(4), 799-819.

- The study analyses the impact of different characteristics of innovation policy mixes on innovation in energy-efficient technologies in the residential sector, exploiting data for 23 OECD countries in 1990-2010.
- First, the role of technology-push, demand-pull and soft policies (aimed at increasing consumers' awareness) is assessed, and then the balance of the policy mix, its comprehensiveness and the interaction with foreign schemes is investigated.
- Results show that policies aiming at stimulating demand have the higher impact, while the more balanced the policy mix is, the larger the impact of schemes. Finally, demand and supply side foreign policies are found to stimulate domestic innovation.

The paper investigates the role of innovation policy in fostering energy-efficient technologies (proxied by patents filed at the European Patent Office) in 23 OECD countries in the period from 1990 to 2010. While empirical analysis of demand and supply side policies is widespread in the economics of innovation literature, the impact of the characteristics of the policy mix is still a relatively little explored domain. This paper estimates the role of the policy mix in stimulating energy-efficient innovation in the residential sector, accounting for its comprehensiveness, i.e. the number of tools put in place, and the balance between different kinds of schemes. In particular, the focus is to understand up to what extent the deployment of different policy tools is going to benefit innovation activities by companies, given the risk of counterproductive interactions between different instruments. Finally, the analysis considers the interactions between foreign and national policies, looking for the role of international spillovers in spurring national innovation activities. The empirical findings reveal a positive impact for both demand and supply side instruments, with the former having the largest effect. Soft policies aimed at increasing consumers' awareness

concerning environmental issues are also found to have a positive role, even though both their statistical significance and economic significance are low. A balanced policy mix is positively related to innovation output, suggesting that having a wide set of alternative schemes benefits eco-innovation. However, a balance between quantity and consistency needs to be met, since a too large number of instruments has a negative feedback on the effectiveness of the policy mix. Finally, foreign policy schemes are found to produce positive spillovers on the domestic production of energy-efficient technologies.

4. Demand-side vs. supply-side technology policies: Hidden treatment and new empirical evidence on the policy mix

Guerzoni, M., & Raiteri, E. (2015). Demand-side vs. supply-side technology policies: Hidden treatment and new empirical evidence on the policy mix. *Research Policy*, 44(3), 726-747.

- The paper estimates the impact of demand- (R&D subsidies and tax credits) and supply- (innovative public procurement) side public innovation policy on companies' innovative behaviour.
- Using data drawn from the Innobarometer Survey covering the period 2006-2008, the authors reveal a positive effect of innovative public procurement on innovation performance of firms, while the impact of subsidies and tax credits alone is null and negligible, respectively.
- The highest effect is found when a policy mix is put in place, in particular for those companies benefiting of the three policy instruments all together.

While the empirical literature analysing the impact of supply-side policies – mostly R&D subsidies – supporting firms' investment in R&D is rich, there is still a lack of evidence addressing the role of innovative public procurement in shaping firms' innovative behaviour. Furthermore, the standard empirical investigation tends to estimate the impact of the chosen policy tool without controlling for the role complementary support schemes may have. If such a hidden treatment is not taken into account, the impact of the policy tool risks to be overestimated, and the effect of non-observed policies or their interactions is not properly measured. Using data on companies drawn from the Innobarometer Survey, covering 27 EU Member States, Norway and Switzerland from 2006 to 2008, the authors perform an impact evaluation of R&D subsidies, R&D tax credits and innovative public procurement. In particular, they evaluate the impact on firms' innovative spending of each policy alone and the effect of the interaction between the different policy schemes. Differently from what is reported by the majority of the literature, the results reveal that, once the hidden treatment is accounted for, the impact of subsidies and tax credits alone is null and small respectively, while a higher and significant effect is found for innovative public procurement. Most importantly, innovative spending of companies that benefit from a mix of the policy schemes is significantly higher compared to firms that did not receive any support. The largest impact is found when the three policy schemes interact.

5. Analyzing interdependencies between policy mixes and technological innovation systems: The case of offshore wind in Germany

Reichardt, K., Negro, S. O., Rogge, K.S., Hekkert, M. P. (2016). Analyzing interdependencies between policy mixes and technological innovation systems: The case of offshore wind in Germany. *Technological Forecasting and Social Change*, 106 (C), 11-21.

- The paper investigates the role of policies for functioning and performance of technological innovation systems (TIS) as well as how TIS developments influenced the evolution of the policy mix for the case of offshore wind in Germany.
- The results suggest highly dynamic interdependencies with reoccurring patterns of systemic problems as well as adjustments of the policy mix to deal with unforeseen or underestimated issues.

- Suggested policy implications: a policy strategy with an ambitious and stable technology-specific long-term target, the use of demand-pull instruments, a credible political commitment towards the technology, as well as a policy mix flexible to adjustments.

A policy intervention is necessary for development and diffusion of the renewable energy technologies in order to prevent consequences of climate change. A main approach for studying emerging technologies in the field of sustainability transitions is technological innovation system (TIS). In contrast to the standard literature on TIS, which usually looks at the role of a single policy instrument on the TIS development, this study considers a more encompassing policy mix. To reconstruct the development of the German offshore wind TIS, the authors use data from a combination of two different sources, in particular: event history data from the European magazine *Wind Power Monthly* in the period 1993-2013 and data on independencies between the TIS and the policy mix from expert interviews from all main stakeholder groups in the TIS. To recreate the evolution of the policy mix, related policy documents were used. The results suggest there were tight and complex interactions between the German offshore wind TIS and the accompanying policy mix. The interdependencies did not only occur between the TIS and policy mix, but also within each other. The policy mix positively influenced TIS development; however, it also contributed to the emergence of new or to the reinforcement of existing systemic problems. The strong and stable commitment to the offshore wind energy by the German authorities and industry advocacy coalitions led to the constant adjustments of the policies and consequently to the continuation of TIS developments.

6. How behavioural additionality can be put into practice in evaluation and policy-making

Gök, A., & Edler, J. (2012). The use of behavioural additionality evaluation in innovation policy making. *Research Evaluation*, 21(4), 306-318.

- This article contributes to deepening the understanding of behavioural additionality by providing a theoretical framework and complementing it with operational examples of how it has been put into practice for both evaluation and policy purposes.
- The authors use three different sources of information: statistical analysis of 171 innovation policy evaluations, semantic analysis of certain behavioural additionality evaluation reports, as well as in-depth evaluation case studies.
- The results put in evidence the complexity of this issue- a comprehensive understanding of behavioural change would need a broad mix of methodologies that cannot be applied in all cases. Also, this calls for a stronger interaction between the different stakeholders involved in the evaluation.

Evaluating innovation policy has become a central aim to assess the role and the impact of policies on the performance of the different target groups. Analysing changes in behaviour through public intervention in innovation policy has received a lot of attention in the literature. The concept of behavioural additionality was first introduced by Buisseret et al (1995)¹ as the persistent change in what the target group of the policy is doing and how they are doing it, whereby this change is attributable to the policy action. However, even though this concept has been increasingly popular in innovation policy evaluation and design, there is still room for clarification and further theorisation of the concept as there is no consensus on how it can be measured for policy practice. As a result, the authors propose an improved conceptualisation of how innovation policy can shape behaviours through its actions. For that, the authors make use of: i) a statistical analysis based on the INNO-Appraisal database which provides information on evaluation reports of EU-25 countries (2002-2007) in a total of 216 reports analysed; ii) a text analysis based on 33 evaluation reports that used the concept of behavioural additionality; iii) a selection of more in-depth case studies to learn in more detail from "good" examples. The article concludes that one of the limitations to

¹ Buisseret, T.J., Cameron, H.M. and Georgiou, L. (1995) 'What Difference does it take- Additionality in the Public Support of R&D in Large Firms', *International Technology Management*, 10: 587-500

systematise the current approaches to behavioural additionality lies in the lack of consensus in academia on the actual meaning of behavioural additionality. The authors also raise attention to the need for more methodological clarification. In particular, a comprehensive understanding of behavioural change would need a broad mix of methodologies that cannot be applied in all cases. Hence they argue in favour of “experimental methodological developments” to allow for a relevant set of approaches that would also cover the rise of new disciplines. Moreover, the complexity of behavioural additionality calls for an intensive discussion with all relevant stakeholders. All in all, there is still room for more research to provide more effective guidelines on how behaviour can be operationalised according to the different contexts.

7. Evaluating firms’ R&D performance using best worst method

Salimi, N., & Rezaei, J. (2018). Evaluating firms’ R&D performance using best worst method. *Evaluation and program planning*, 66, 147-155.

- Using survey data, this paper measures the R&D performance of 50 high-tech SMEs in the Netherlands with a methodology that takes a multi criteria perspective.
- The approach is useful for R&D managers as it allows for the identification of key factors determining R&D performance within a set of indicators at different levels of decision making.
- The results from the assessment of performance of the surveyed high-tech SMEs reveal that the innovation and learning perspective is the most important R&D perspective in the Netherland.

This paper proposes a way to measure R&D performance within firms taking into account a set of different perspectives. The method takes into account that companies usually have heterogeneous objectives when measuring the performance of their R&D activities. The Best Worst Method (BWM) is used to construct weights of importance of R&D indicators and the results are used to quantify the R&D performance of 50 Dutch high-tech SMEs from a survey conducted among SMEs and R&D experts. The method is a structured pairwise comparison system within the framework of criteria that offer four different perspectives; namely the customer, the internal business, the innovation and learning and finally the financial perspective. The method proposed to assess these different aspects and to determine the respective weights for overall firm performance. It enables R&D managers to identify key factors to improve R&D performance and outcomes. The results show that the innovation and learning perspective is the most important R&D perspective for the surveyed high-tech SMEs in the Netherland. This result fits into the recent trend of knowledge creation and innovation becoming the core elements of firm’s R&D strategies. Measuring outcome is crucial as investment in R&D is both risky and costly. The authors highlight the main causes for this paradigm shift. Firstly, product lifecycles shortened and secondly, products and services are introduced to the market at a higher speed. Finally, the pace of innovation activity has increased leading to a greater need for developing and applying new knowledge.

8. A new approach to measuring technological innovation efficiency

Cruz-Cázares, C., Bayona-Sáez, C., & García-Marco, T. (2013). You can’t manage right what you can’t measure well: Technological innovation efficiency. *Research Policy*, 42(6-7), 1239-1250.

- Overall, the paper finds that the key driver for increased firm performance is the efficiency with which innovation inputs are converted into innovation outputs.
- The authors propose a methodological novelty to capture and measure less ambiguously the effects of technological innovation on firm performance.
- The paper uses firm-level data from the Spanish manufacturing sector over the period 1992-2005.

With this paper, the authors address empirical inconclusive results when it comes to the way innovation impacts on firm performance. The paper argues that better performance is actually driven by increased technological efficiency, instead of simply directly linking innovation inputs, such as R&D expenditure, to firm performance. In particular, technological efficiency is defined as *the relative capability of a firm to maximize innovation outputs given a certain quantity of innovation inputs* involved in the production process. The paper makes use of an unbalanced panel of Spanish innovators and non-innovators in the manufacturing sector over 1990-2005 to test two hypotheses: i) that technological innovation efficiency will increase firm performance, and ii) that this effect will depend on the level of technological intensity and the size of the firm. The results confirm a positive effect of technological innovation efficiency on firm performance. Moreover, the effect of technological innovation efficiency is the greatest for high-technology (HT) firms, while being very small for low- and medium-low (LML) technology firms. According to the authors, this finding illustrates a stronger reliance of HT firms on creating competitive advantages from technological innovation throughout time. Also, as expected, large firms benefit from a bigger effect of technological innovation efficiency on their performance due to their pool of resources and their stronger ability to achieve economies of scale when compared to smaller firms.

9. Performance evaluation of R&D active firms

Khoshnevis, P., & Teirlinck, P. (2018). Performance evaluation of R&D active firms. *Socio-Economic Planning Sciences*, 61, 16-28.

- Measuring the efficiency of utilisation of R&D resources within enterprises is an important topic in the area of policy impact assessment.
- In this paper a methodology which simultaneously evaluates multiple R&D inputs and outputs is used to gauge the performance of Belgian R&D active firms in 2008 and 2009.
- The main finding of this empirical investigation is that for the selected sample of firms positive returns to scale are present – more R&D inputs translate into higher efficiency and a better performance.

Determining the efficiency of firms in the utilisation and allocation of R&D resources is one key area of research in the quest to solve the “European paradox” of high quality research and a simultaneous weakness in wealth generating innovation activity. R&D performance evaluation is hampered by a lagged effect of R&D activities on innovation outcome – a high level of input does not translate automatically into an increase in R&D output. This paper uses a multiple indicators method to determine a firm’s performance level using data envelopment analysis (DEA). This technique is based on a linear programming model to simultaneously evaluate the relative efficiency of multiple inputs and outputs. It can be computed by using constant or variable returns-to-scale. One advantage of the DEA analysis is that an evaluation can be carried out in a context in which the importance of various R&D inputs and outputs are not determined. According to model assumptions, a firm can improve its efficiency by changing the size of its operations. For the empirical application of the model, the authors use Belgian firm level data from the OECD business R&D survey for the years 2008 and 2009. The net added value is measured as the wealth creation of the enterprise before distribution to shareholders, bondholders, employees, governments and reinvestment as well as turnover per employee. Furthermore, firms are categorised according to sector of activity at the global frontier and size. The results show that, on average, R&D active firms are prone to both technological inefficiency and a scale size problem. However, whereas the main source of inefficiency for small firms are the size of operations, or scale size problems, large companies tend to be obstructed by technical inefficiency or management and administration problems. The results also demonstrate increasing returns to scale, hinting at a positive correlation between R&D inputs and performance and efficiency

10. Research subsidies, industry-university cooperation and innovation

Szücs, F. (2018). Research subsidies, industry–university cooperation and innovation. *Research Policy*, 47(7), 1256-1266.

- The paper analyses the impact of the effect of EU funding on innovation outcomes of 2187 European firms between 2005 and 2014.
- No positive and significant impact of funding from the Seventh Framework Programme on the innovativeness, as measured by patenting activity, of firms was established. However, the results point towards important effects on knowledge creation within the projects.
- Knowledge spillovers together with radical innovation activity were more likely to occur in cooperation projects of large size and in conjunction with an academic institution of high quality.

This paper evaluates the impact on innovation activity of the Seventh Framework Programme of the European Commission, making use of data of 2187 participating firms between 2005 and 2014. The study uses a sample of matched firms, consisting of both recipients and comparable enterprises which did not receive funding, to estimate the effect of funding on innovation outcomes. A positive effect was not established, but the large heterogeneity of outcomes conceals some valuable insights such as the presence of knowledge spillovers and project size effects. The paper allows for a distinction between effects on universities, public research institutes and cooperation projects with universities. The results of the quantitative evaluation suggest that cooperation with universities leads to higher knowledge spillovers. Furthermore, more novel or radical innovations tend to come out of projects with a more important number of participants. The quality of the academic institution also matters, with highly ranked universities achieving better innovation outcomes relative to lower ranked higher education institutions. The measurable impact identified is hence related to knowledge creation within the group of participants which grows as the size of the project increases. This finding suggests that future funding programmes should allow for the formation of large teams so as to enable spillover effects as well as radical innovation.