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

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1. What is the relationship between public and private investment in science, research and innovation?

Economics Insight (2015). What is the relationship between public and private investment in science, research and innovation. London: Economic Insight.

- By performing a quantitative analysis using data from 1997 to 2012, the authors establish a crowding-in effect: a 1% increase in public expenditure on R&D leads to an increase in private expenditure of between 0.48% and 0.68%. In monetary terms, an additional pound of public research investment is associated with an increase in private expenditure of £1.13-£1.60.
- The paper finds a crowding-in effect of publicly funded research conducted within Higher Education Institutions (HEIs) on the amount of private funding of research.
- Budget cuts of public funding of research may undermine subsequent private sector R&D investments; keeping the science budget constant gives rise to an estimated additional £1.2bn of private sector investment that would have not been realised if the R&D budget had been cut.
- The study uses annual data on Gross domestic expenditure on R&D (GERD) from 1997 to 2012 from UK's Office for National Statistics (ONS).

This report was commissioned by UK's Department for Business, Innovation and Skills (BIS) to examine the relationship between public and private investment into science, research and innovation. It discusses the hypothesis of additionality of public expenditure via the two main routes commonly suggested in the literature: i) One pound increase in private expenditure arising from an extra pound in public expenditure, and ii) the percentage increase in private investment after a 1% increase in public investment. For that, the authors use GERD annual data from 1997 to 2012 from UK's Office for National Statistics (ONS). The results indicate that a 1% increase in public investment gives rises to between a 0.48% and 0.68% increase in private investments, controlling for other factors that are likely to influence the level of private funding. In addition, this effect is not immediate, with a lag of approximately one to two years. These findings are complemented by an alternative analysis based on data from the Higher Education Statistics Agency (HESA), which collects financial information on the activities of all UK higher education institutions (HEI), for the period 2003/04 to 2012/13. Estimates point as well to a crowding-in effect of publicly funded research conducted within HEIs on the amount of private funding of research conducted within HEIs. The range of estimates of coefficients of additionality are from 0.25 to 0.81. The study also attempts to estimate the monetary value of the crowding-in effect: i) for each pound of public research funding there will be an increase in private funding of between £1.13 and £1.60, and ii) for each pound of public-financed HEI research, there will be an additional £0.29 of private funding of HEI research and £1.07 of research conducted elsewhere.

2. The Domino effects of federal research funding

Lanahan, L., Graddy-Reed, A., & Feldman, M. P. (2016). The domino effects of federal research funding. *PLoS one*, 11(6), e0157325.

- Overall, US federal funding is found to crowd-in investments from other investment sources including industry research funding though the magnitude of its impacts varies across academic division, research capacity and institutional control.
- Federal funding has a complementary role to state and private R&D investment.
- The paper uses data from the National Science Foundation Higher Education, Research and Development (NSF HERD Survey).

The US Congress Centre has often debated on whether federal investment in research crowds out or induces investment from other funding sources. This paper examines the hypothesis that federal investment supports high-risk research that typically has long time horizons and may induce additional investment by other funding sources such as private sector R&D. The data used come from the National Science Foundation Higher Education, Research and Development (NSF HERD) Survey which collects information from university respondents in US Higher Education institutions on the allocation of annual research expenditures to academic fields by source. As a result, this research looks at the level of academic science fields within the university context instead of the aggregate institutional level. Overall, the results show that a 1% increase in federal research spending induces a 0.468% increase in private research funding. The magnitude of the results also varies, for instance, according to the academic division: a 1% increase in federal research funding leads to additional private research spending of 0.445% in physical sciences, 0.537% in life sciences, and this effect is the strongest in the engineering division (0.579% increase).

3. Quantifying the economic impact of government and charity funding of medical research on private research and development funding in the United Kingdom

Sussex, J., Feng, Y., Mestre-Ferrandiz, J., Pistollato, M., Hafner, M., Burridge, P., & Grant, J. (2016). Quantifying the economic impact of government and charity funding of medical research on private research and development funding in the United Kingdom. *BMC medicine*, 14(1), 32.

- The results confirm that public biomedical and health research expenditure crowds in additional private pharmaceutical spending in R&D: an additional pound of public research expenditure is associated with an additional £0.83–£1.07 of private sector R&D spend in the UK.
- The paper builds on UK data on public and private R&D investment from 1982-2012 covering ten different categories of diseases.

This study estimates the sign and the magnitude of the effect of public R&D investments in biomedical and health research in the United Kingdom on subsequent private pharmaceutical sector R&D expenditure in the country. The authors computed a 31-year time series with data on public (including both government and charities) and private R&D investment from 1982-2012 covering ten different categories of diseases. The paper concludes that: i) an additional pound of public R&D expenditure induces additional private R&D investments in an order of magnitude between £0.83 and £1.07, ii) 44% of the additional private R&D expenditure occurs within 1 year, with the remainder accumulating over decades, and iii) the resulting spill-over effect generates an annual economic rate of return to public biomedical and health research in the UK of 15-18%.

4. The productivity effect of public R&D in the Netherlands

Soete, L., Verspagen, B., Ziesemer, T. (2017). The productivity effect of public R&D in the Netherlands. Working Papers of the United Nations University-Maastricht Economic and Social Research Institute on Innovation and Technology (MERIT), n. 21.

- The paper analyses the impact of public R&D investment on GDP and TFP growth, as well as on private R&D, in the Netherlands in the period 1968-2014.
- The authors estimate the impact of additional public R&D investment under different scenarios, tackling the main issues with the criticalities in the approach of the original paper.
- Results suggest that increased public investment in R&D has long-term effects on both GDP and TFP growth, while crowding in investment by the business sector. Crowding out is found in the very long term and only in case the shock on public R&D investment is simulated as a temporary policy.

Economic theory and evidence suggest that technological innovation is the main driver of economic growth in the long term. Similarly, there was shared consensus that the returns of public investment in R&D were significant and positive, in terms of both total factor productivity and overall GDP growth. However, this view has been recently challenged from two different perspectives. First, that the returns of public investments in R&D are null or negative, while a positive impact is to be found only for R&D activities carried out by the business sector. Second, that excessive public investment, even in the domain of research and technology, may have the adverse effect of crowding out private investment. The authors assess the two issues, expanding the work by van Elk et al. (2015)¹ which found negative or null returns, while a weak positive effect was in place only in case the heterogeneity in the sample of countries was specifically accounted for in the analysis. Building on the last point, the paper uses data for the Netherlands in the period 1968-2014. The methodology accounts for interactions among variables and allows to assess the long run effect of a simulated shock on public R&D. The results suggest that public R&D investment has a positive effect on GDP and TFP growth in any specification of the model. Similarly, public R&D and foreign business R&D are found to be complementary, i.e. moving in the same direction. For what concerns the relationship between public R&D and national private R&D, the impact varies according to whether the shock to public R&D is temporary or permanent. In the first case, the effect on business investment is positive for around thirty years for then becoming negative in the very long run, e.g. some crowding out is in place. In the second case, crowding in is always observed, even if the effect is slowly decreasing over time. A similar result is obtained if foreign public R&D is increased together with national public investment.

5. The economic significance of the UK science base. A report for the campaign for science and engineering

Haskel, J., Hughes, A., Bascavusoglu-Moreau, E. (2014). The economic significance of the UK science base. A Report for the Campaign for Science and Engineering. UK Innovation Research Centre, London.

- The paper investigates the relevance of public funding of the science base in the UK in terms of leveraging private R&D investment, fostering public research – private business cooperation and the overall effect on industry-level total factor productivity.
- Data show that the universities receiving higher research funding are more likely to set up interactions with business R&D, revealing also that private actors' willingness to pay is high, i.e. they place value upon public research.
- The evidence suggests that multinationals' decisions to locate R&D investment are affected by the quality of the public science base, in the pharmaceutical sector for what concerns the specific UK case.
- State funded research is positively correlated with TFP growth, in particular by fostering the impact of private research investment, suggesting complementarity at the industry level.

¹ Van Elk, R., Verspagen, B., Ter Weel, B., Van der Wiel, K., & Wouterse, B. (2015). A macroeconomic analysis of the returns to public R&D investments. CPB Netherlands Bureau for Economic Policy Analysis, 313.

The report sets in the overall discussion on the relevance of public investment in research and the existence of a strong national research base for leveraging business investment in R&D, attraction of foreign investment and for improving productivity growth. Theoretically, from a system perspective, domestic public R&D is fundamental to enhance the absorptive capacity of the economy since it provides human capital and knowledge for both the public and the private sector. From this point of view, domestic "pure" research can leverage and attract domestic and foreign private R&D respectively, i.e. crowding in holds. The authors analyse the specificities of the UK case. In particular, the report results from the existing literature which shows that business puts high value on the UK's technological capacity in producing knowledge relevant to industries, suggesting a pull role for public research. This effect is particularly evident in the UK pharmaceutical industry, which tends to locate its research activities close to universities. Furthermore universities which receive the higher shares of public funds are also more likely to receive external funding from the business sector, suggesting that the latter is willing to pay for the value of public research. In addition, pure business-public cooperation in the UK, while not extremely large, is especially high in the manufacturing sector and in services, the former being a high R&D intensive industry. Finally, results from an econometric estimation suggest that private R&D investment is positively correlated with industrial TFP growth, and R&D that is publicly funded and performed by the government boosts such a positive correlation.

6. Does government spending crowd out R&D Investment? evidence from government-dependent firms and their peers

Ngo, P., Stanfield, J. (2017). Does Government Spending Crowd Out R&D Investment? Evidence from Government-Dependent Firms and Their Peers. FIRN Research Paper No. 2581273

- The paper investigates the impact of a positive shock to federal government spending in the United States on business R&D expenditure.
- The relationship is investigated across three different types of companies: government-dependent firms, industry-peer firms and non-peer firms.
- Results suggest that an increase in federal government spending increases R&D investment by government-dependent companies. However, R&D investment by industry-peer firms is crowded-out via the channel of the managers' choice to adjust budget to keep real earnings up in the short term.

The study analyses the hypothesis that increased public spending crowds out private R&D investment in the United States² using a sample of firms in the 1990-2013 period. The authors focus on three different kind of companies, distinguishing between those firms who strongly depend on government spending for their activities, their industry peers and competitors, and companies in different industries. A shock in public spending may increase expected earning and profitability of government-dependend companies, while at the same time decreasing peer firms relative performance. The paper investigates the impact of this mechanism on peer-firms' managers incentives, under the hypothesis that they will cut R&D spending to keep relative profits as high, due to reputation and compensation incentives. Results confirm such a hypothesis. First, government dependent companies do increase their R&D expenditure following a rise in public spending, while industry-peer firms react in the opposite direction, i.e. their R&D investment is crowded out. However, the relationship is not confirmed in the opposite direction: a reduction in public spending does not lead to an increase in peer-firms R&D investment. Different mechanisms are investigated, as the effect of macroeconomic variables, such as interest rates and tax channels, or micro-founded free-riding behaviour by peer-companies to benefit from knowledge spillovers. Both the macro and the micro alternative hypothesis are rejected; in particular, the positive externality channel is discarded since the results are stronger in less-innovative states where knowledge spillovers are less likely.

² The authors consider changes in the discretionary share (around 30%) of the federal budget, since there is not overall R&D budget or special consideration of R&D for most of the US agencies.

7. Context and the role of policies to attract foreign R&D in Europe

Rodríguez-Pose, A., Wilkie, C. (2016). Context and the role of policies to attract foreign R&D in Europe. *European Planning Studies*, 24(11), 2014-2035.

- The study focuses on the effectiveness of direct and indirect support policies in attracting foreign R&D investment of multinational companies in a sample of 29 European countries in the period 1990-2012.
- Direct measures effectively contribute to attract foreign private R&D investment, while the results do not confirm a significant role of indirect support.
- R&D investment location decisions by multinationals are positively encouraged by socio-economically contexts most suitable for knowledge intensive activities, including the availability of skills and human capital, which in turn depend on public investment in R&D and education (HERD).

Multinational companies are an important contribution to national business R&D investment, as they tend to decentralise their activities beyond their home country and, accordingly, countries have been implementing policies schemes to attract such an R&D investment. The paper investigates the effectiveness of public R&D support schemes in such an effort for a set of European economies. Three main research questions are considered. First, whether a positive relationship between direct financial support and foreign business R&D exists. Second, whether indirect support instruments, e.g. tax incentives, are effective in attracting foreign R&D investment and how do they perform compared to direct support schemes. Finally, the conditioning effect socio-economic conditions exert on the effectiveness of support policies is analysed. In particular, demand-side, such as market size, and supply-side are considered. Among the latter, the availability of skilled human capital and the overall innovative capacity of the economy are included, proxied respectively by public investment in higher education research and development (HERD) and total gross expenditure on R&D (GERD). Using a sample of 29 European economies in the period 1990-2012, the study reveals a positive relationship between direct financial support and foreign business R&D, while tax incentives do not seem to have any effect. The overall economic and technological conditions are found to have a significant role. In particular, the overall innovative capacity (measured by GERD) of the country is positively correlated with foreign business R&D, both directly and through improving the attractive role of direct financial support. Higher levels of public investment in higher education R&D are positively associated with higher foreign private R&D invested in the country. Therefore, the evidence suggests that the provision of direct financial support may be effective in attracting multinational investment in R&D, but that the existence of overall conditions favourable to innovative activities are fundamental in driving the results. Countries should therefore first focus on the latter, for instance by increasing their HERD to improve the human capital base of the economy, as part of an integrated strategy to attract private R&D from abroad.

8. The role of spillovers in research and development expenditure in Australian industries

Bakhtiari, S., & Breunig, R. (2018). The role of spillovers in research and development expenditure in Australian industries. *Economics of Innovation and New Technology*, 27(1), 14-38.

- The results show that the effects of public research expenditure depend upon the source: while R&D expenditure by academia has a positive influence on a firm's R&D expenditure, direct government spending on R&D seems to crowd-out private R&D.
- A shift of expenditure from government R&D to academic R&D could potentially stimulate private R&D expenditure. At the same time, government agencies should consider a shift towards more basic research due to higher spillovers found.
- The paper uses R&D data on Australian firms from 2001 to 2011.

The paper discusses the existence of R&D spillovers from external sources (academia, federal and state government) to the firm and the implications it may have to firm's decision to invest (including how much) in R&D. The database consists of firm-level data on R&D expenditure provided by the Australian Department of Industry's R&D Tax Concession programme for the period 2001 to 2011. The modelling and measurement of R&D spillovers followed in the paper account for the different effects of the various sources of spillover. The main findings are that i) academic expenditure seems to induce private R&D expenditure, while ii) state and federal direct government spending crowds-out private R&D. The paper argues that if government agencies are already undertaking research projects in certain areas, firms feel less incentivised to increase R&D activity. Moreover, this result may be linked to the type of research expenditures performed by the government when compared to academia. Previous reports from the Australian Bureau of Statistics (ABS) indicate that more than 60% of R&D expenditure in academia is for basic research, while R&D spending in applied research accounts for 70% of the total R&D expenditure of state and federal governments. As a result, the authors offer as possible explanations i) potentially higher knowledge spillovers from basic research than applied research, and ii) different approaches from the government and academia to spill-over their spending in research (e.g. in regards communication). Finally, the paper recommends a shift of expenditure from government R&D to academic R&D in order to stimulate private R&D expenditure, and that government agencies should consider a shift towards more basic research.

9. Public R&D investments and private-sector patenting: evidence from NIH funding rules

Azoulay, P., Zivin, J. S. G., Li, D., & Sampat, B. N. (2015). Public R&D investments and private-sector patenting: evidence from NIH funding rules (No. w20889). National Bureau of Economic Research.

- Public R&D investment seems to influence positively innovation in firms.
- The paper uses data from NIH-funded grants from 1980-2005, and biomedical patents granted between 1980 and 2012.
- The results indicate that scientific grant funding at NIH increases patenting activity in biopharmaceutical companies: a \$10 million increase in funding for an area leads to 2.3 additional patents.

The study reflects upon the channels through which public-funded research can generate spillover effects to innovation in firms, including firms' commercialisation of research and inventions produced in universities. In this context, the authors develop measures of private commercial output linked to public-funded research in life sciences. The main outcome variable is patenting by private sector biopharmaceutical firms. Data come from a combination of four main sources, notably: Administrative data on the National Institutes of Health (NIH) grant applications from the IMPAC II database, publication data from PubMed including information on grant acknowledgements, patent data from the USPTO, and information on patents related to FDA-approved drugs from the FDA's "Orange Book" and IMS-Health. Hence the final dataset takes into consideration the different linkages between the universe of NIH-funded grants from 1980-2005, and the universe of biomedical patents granted between 1980-2012. The main findings are: i) NIH investments in a certain research area boost subsequent patenting activity of firms in that area. In particular, a \$10 million increase in funding for an area leads to 2.3 additional patents; ii) there seem to be strong cross-disease spillovers in the biomedical sector which hints at the importance of incorporating a more cross-cutting organisation of public biomedical research in detriment of disease-specific institutes in NIH.

10. The retreat of public research and its adverse consequences on innovation

Archibugi, D., Filippetti, A. (2018). The retreat of public research and its adverse consequences on innovation. *Technological Forecasting and Social Change*, 127, 97-111.

- Set in the overall trend of decreasing public R&D intensity worldwide, the paper analyses the differences between public and private research activities using the lens of the public goods theory.
- Public and private R&D differ substantially in terms of resources allocation criteria and the scope of R&D, the degree of excludability in the use and diffusion of knowledge. These differences are key drivers of the process of innovation diffusion and the direction of technological advance.
- The major trend of retreat of public R&D in OECD economies may have adverse consequences for the future avenues of the production of knowledge and its openness, with long-term implications for the competitiveness of industry and the tackle of societal challenges.

Using data from 1983 to 2013, the authors report a drastic reduction in the share of public financed R&D to GDP from 0.82% to 0.67% in most OECD countries, with the notable exception of South Korea, while industry-financed R&D has increased from 0.96% to 1.44% in the same period. As a result, only 28.3% of R&D expenditure is financed by the public sector in 2013, down from 44.2% in 1983. While this overall retreat sets within the general reduction of public expenditure, two key differences in how public and private R&D are undertaken are relevant for future prospects of technological advance and innovation diffusion. First, the allocation of resources among different R&D activities in the private sector is determined by market forces and driven by profit seeking, while the political process drives the allocation in the public R&D domain, based on what is considered relevant for the overall economy and society. This is a key determinant of the possible outcomes of science. As long as the public sector invests to set the direction of technological advance for the benefit of society and the overall economy beyond fixing market failures, a reduction in public R&D can affect long-term economic and technological prospects. Second, business R&D is characterised by a higher degree of partial excludability: while it is harder to exclude other actors from the use of knowledge compared to material products, industrial technology is largely firm specific, and profit-seeking agents invest resources to exclude others and protect their rents. These factors contribute to make knowledge a quasi-public good, i.e. a good with both public and private characteristics, hence partially excludable. Therefore, a reduction in public investment in R&D may hamper the open dimension of innovation, its long-term diffusion and production patterns. The authors conclude that, while policies encouraging knowledge transfers and public-private cooperation are fundamental, public R&D needs not to be neglected, given its nature and scope, and its role for the future of technology creation and diffusion and for addressing economic and societal challenges.