Measuring the Value Contributions of Intangibles: A Data-Driven Approach

Rebecca Riley
King's College London
rebecca.riley@kcl.ac.uk

Leonard Nakamura
Federal Reserve Bank of Philadelphia

Oleksii Romanko
King's College London

Intangible investments (e.g. investments in R&D, software and databases, management and other organizational capital) are increasingly acknowledged as crucial to firms' performance (see e.g. Bender et al., 2018; Haskel and Westlake, 2018; Sadun et al., 2017). Although methods for measuring these investments is still evolving (Martin, 2019), official estimates suggest investments in intangibles are of a similar magnitude to or greater than investments in tangible assets such as buildings, machinery and equipment (ONS, 2021).

Much has been learnt about the patterns of intangible investment in the last decade following the seminal work of Corrado, Hulten and Sichel (2006), which proposed a framework for measuring intangible investment and capital and led to the development of new statistics on intangibles (see e.g. the INTAN-Invest database; Corrado, Haskel, Jona-Lasinio and Iommi, 2016). In this paper we are less concerned with the measurement of intangible investments, but rather focus on how we might measure the value contribution of intangible investments.

Intangible capital is likely to behave differently in the production process to tangible capital. For example, Haskel and Westlake (2018) characterize intangible capital by its scalability, sunkenness, spillovers, and synergy in production. Furthermore, the returns to intangibles such as R&D may exhibit fat tails, with a small proportion of firms having relatively good returns and most having relatively poor returns. For these reasons the contributions of intangibles to productivity and growth may be difficult to capture in standard production functions or using growth accounting techniques. Indeed, standard methodologies may underestimate the contributions to growth of intangible investments irrespective of whether these inputs are correctly measured.

Given these complexities we propose a theoretically agnostic approach to exploring the value contribution of intangible investments. We use rich information on firms' uses of intangibles and their outputs to explore the value contribution of intangible investments in a data-driven approach. We consider different combinations of inputs and investment sequences, constructing polynomials and cross-terms of different degrees and their distribution over time. These terms are then used as a feature space to construct a model relating inputs to company output, using a

non-parametric datadriven approach. We consider generalized additive models, Bayesian averaging of classical estimates (Sala-i-Martin, Doppelhofer and Miller, 2004) and modern data-science extreme gradient boosting models, XGBoost (Nielsen, 2016).

Our main dataset is the UK Annual Business Survey and Annual Respondents Database X covering approximately 50,000 businesses and around two thirds of employees in the UK non-farm nonfinancial business sector. These datasets include information on firms' employment, output, use of intermediate inputs and capital expenditures. We use the information in these datasets on firms' capital expenditures on software and databases and their intermediate expenditures on advertising and marketing, as well as computer and telecommunication services. Firms' R&D expenditures are linked from the Business Expenditure on Research and Development survey. This information gives us a rich picture of firms' use of intangibles. We also explore information on management practices from the UK Management Practices Survey and the UK Management and Expectations Survey, although these are available only for very recent years.

We limit our attention to firms that had at least 400 employees at some point during the period 2002 to 2019; expenditures and investments in digital and intangibles are often unrecorded for smaller firms and the longitudinal dimension is sparse for smaller firms. Our sample includes more than 9,000 unique firms and more than 84,000 firm-year observations in total. The longitudinal aspect of our data allows us to identify high growth and shrinking firms. Investments in intangible assets are highly skewed, with relatively few firms making large investments in software and R&D. Expenditures on digital services are more evenly distributed across firms than investments in intangibles, although these too are right-skewed. R&D expenditures co-occur with software and branding investments.

Using this rich dataset on firm performance and investments in intangibles, we find that flexible modelling approaches outperform standard production function specifications in terms of their ability to explaining the variation in productivity across firms. We find that intangible investments typically affect production in synergy with other production inputs. Digital expenditures are an important feature of higher productivity performance throughout the productivity distribution. R&D and branding investment distinguish the top performers from the rest. Our results point to the importance of extending existing frameworks for measuring the productivity contributions of intangible assets.

References:

Bender, Bloom, Card, Van Reenen, Wolter (2018). “Management Practices, Workforce Selection, and Productivity”, Journal of Labor Economics, Vol. 36, No. S1, p. S371–S409.

Corrado, Haskel, Jona-Lasinio and Iommi (2016). “Intangible investment in the EU and US before and since the Great Recession and its contribution to productivity growth” in “Investment and Investment Finance in Europe” , Chapter 2, pp. 73-102, European Investment Bank Report, November.

Corrado, Hulten and Sichel (2006). “Intangible capital and economic growth”, Finance and Economics Discussion Series 2006-24, Board of Governors of the Federal Reserve System. Haskel and Westlake (2018). Capitalism without Capital. Princeton University Press.

Martin (2019). “Measuring the Other Half: New Measures of Intangible Investment from the ONS”, National Institute Economic Review, Vol 249, pp. R17-R29.

Nielsen (2016). “Tree Boosting With XGBoost - Why Does XGBoost Win "Every" Machine Learning Competition?”, Department of Mathematical Sciences, Norwegian University of Science and Technology. Office for National Statistics (2021). Investment in intangible assets in the UK: 2018, April.

Sadun, Bloom and Van Reenen (2017). “Why Do We Undervalue Competent Management?”, Harvard Business Review, September–October issue, pp.120–127.

Sala-i-Martin, Doppelhofer and Miller (2004). “Determinants of long-term growth: A Bayesian Averaging of Classical Estimates (BACE) approach”, American Economic Review, vol. 94(4), pp. 813–35.