Productivity Effects of Knowledge-based Capital – New Evidence from German Firm-level Data

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Firms in developed economies are under great competitive pressure to constantly innovate. Macroeconomic studies have shown that investment in so-called knowledge-based capital (KBC) is an important instrument to face this pressure. This is further exemplified by the fact that firms in the German private sector invest an estimated 10% of value-added in KBC, an amount of almost similar magnitude to that invested in physical capital. Yet, most of the evidence on the importance of KBC for competitiveness and growth is generally based on aggregated data. So far, findings relating to the impact of KBC on firm development at the micro level have been limited by data availability.

The present analysis seeks to close this gap by focusing on the following questions: What is the size of total investment in KBC and its distribution across firms in Germany? What effect do these investments have on value creation and the productivity growth of firms? How does this effect differ across company size and industry? Are different KBC elements complements or substitutes?

The dataset used for the econometric investigation merges a number of elements from different statistical agencies. The main source of information is the official company register of Germany (Amtliche Firmendaten in Deutschland, AFiD-panel). This data contains, inter alia, investments in software, Research and Development (R&D) and intellectual property rights. In order to estimate organizational capital at firm level, we use Linked Employer-Employee Data, provided by the Institute for Employment Research (IAB) of the Federal Employment Agency. In this dataset we directly observe the earnings of managers. The final dataset covers more than 1 million firms in mining and quarrying, manufacturing, transport and storage, information and communication, and professional services for the period 2003 to 2014.

Our descriptive results show, firstly, that the bulk of aggregate investments in the KBC elements covered here is concentrated in a small number of economic sectors. Investments in R&D are predominantly driven by seven research-intensive industries and two knowledge-intensive service sectors. In particular, around one-third of total investment in business R&D is attributable to the motor vehicle industry alone. Regarding spending on software, telecommunications and

information technology (IT) services are the main actors. A similar pattern of concentration can be found when looking at spending on intellectual property products. In contrast, all industries seem to devote at least some resources to organisational capital.

Secondly, investment intensity, defined as the ratio of investment to value-added, shows that the sectors which dominate total KBC investment do so because they invest the highest share of their value-added in KBC, and not because they are the large sectors in the economy.

Finally, within each industry, we observe large disparities in the share of firms that are responsible for KBC investment, and find a disproportionally large influence for firms with more than 250 employees. In sectors with important investments in R&D and software, we observe that the investment effort is undertaken by a large fraction of the firms, between 40 and 50%. On the contrary, when investment intensity is low, investments tend to be carried out by fewer than 20% of the firms. This is particularly striking for spending on patents and licenses, where the share of firms that spend on these assets is low across all sectors. Organisational capital again stands out as an exception, as the share of investing firms is particularly high across sectors, reaching up to 70% of firms investing in certain manufacturing industries.

Our econometric analysis is based on the estimation of a structural model of production, following the methodology of Ackerberg, Caves and Frazer (2015). We test alternative models of the production function to determine whether the different classes of KBC assets have a direct effect on a firm's value-added, alongside traditional inputs such as labour and physical capital, or whether they influence a firm's total factor productivity (TFP). For each model, we further test the sensitivity of our results to assumptions on the functional form of the production function.

Modelling KBC elements as production inputs yields the following results: Increases in the capital stock of R&D lead to higher value-added, with the largest effects being measured in the R&D-intensive industries. However, there are a number of sectors for which we do not observe a significant effect for R&D, especially in business services. The stock of software capital shows a different pattern. An increase is associated with higher value-added in the services sectors, no such effect is measured in many manufacturing industries. In addition, in the services sector, software appears to have a larger effect on value-added than licenses and patents or R&D. Higher organizational capital stock results in higher value-added across industries.

When measured against productivity rather than output, the effects of KBC seem more pronounced and statistically robust. We find significant effects for all KBC elements in most sectors of the economy. In particular, the elasticity of software is significant in the manufacturing sector, and often of a comparable magnitude to the elasticity of R&D. Overall, we find that different elements dominate in different industries, highlighting the importance of modelling the bundle of KBC elements, rather than focusing on an individual assets, such as R&D. We further split our analysis between small and medium enterprises (SMEs), and large firms, but find no weaker effect of KBC elements in small firms.

In a final step, we seek to shed light on the degree of complementarity or substitutability between

the different elements of the KBC bundle, by using the statistical test proposed in Carree (2011). We find evidence that software and organizational capital are substitutable in many industries, in both in the manufacturing and services sectors. Investments in software solutions can thus lead to savings in organizational expenses without negatively impacting productivity or gross added value. For the other elements, we tend to find evidence of complementarity especially in the manufacturing sector. It follows from this that sustained increases in productivity cannot be achieved solely through the expansion of investment in one of the elements alone, but through accompanying increases in other KBC elements.