Science and Public Policy, 2025, **52**, 950–959
https://doi.org/10.1093/scipol/scaf045
Advance Access Publication Date: 19 December 2025
Special Section

R&D effort and knowledge sourcing: the search for better profitability and higher growth

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In Europe, investments in internal and external research and development (R&D), innovation, and organizational capabilities significantly impact productivity and profits, particularly during the COVID-19 pandemic. Using GLOBALINTO intangible capital survey on Europe, a focus is placed on those factors that generate growth in productivity and employment. The core element of growth-promoting policies is internal R&D in firms with high business value through innovations. Other important sources of growth are digitalization and organizational agility. External R&D relates to higher productivity but not to growth. Both R&D and intangibles, in general, improve financial allocation rather than resulting in high fixed costs. Sound asset turnover limits the necessity for public intervention, as R&D improves the level of financial allocation efficiency.

Keywords: intangible capital; R&D; performance; innovation policy.

1. Introduction

Productivity growth in Europe has been slowing since 2006, according to Goldin et al. (2024). Productivity, innovation, research and development (R&D) investment, and knowledge spillovers are areas of relative underperformance in many European countries (OECD 2015) and in Europe vis-à-vis the United States (Bloom et al. 2012; Hall et al. 2009; Mohnen et al. 2019). Experts suggest that this might be due to the mismeasurement of capitalization resulting from the growth of intangible services, which are often considered expenses rather than investments when used in other sectors (Crouzet and Eberly 2021). As suggested by Haskel and Westlake (2022), to boost the intangible economy, companies should focus on a broad set of intangibles and develop innovations that cover wide ranges.

While a brief period of low growth in intangibles followed the 2009 financial crisis, intangible services moderately increased since 2011 (Corrado et al. 2016, 2022; Piekkola 2018). Bauer and Genty (2022) found intangible investments to be more resilient to financial crises than investment in tangibles. Using the same Globalinto intangible survey that is used in this study, Piekkola (2024) analysed the growth effect of total intangibles such as R&D, OC, branding, and design. The results revealed the relationships between a broad set of intangibles and high growth in both productivity and employment, but this was only the case in knowledge services (KIS).[1] In all other cases, the business value of investment (BVI) was the primary source of productivity and employment growth, which indicates a significant improvement in products and services per turnover. This analysis is aimed at determining whether internal or external R&D serves as the unique source of growth beyond what can be explained by BVI. Another research topic involves whether R&D improves the financial allocation of fixed assets.

The analysis relies on data from the Globalinto Intangible Capital survey (Caloghirou et al. 2024).[2] This survey is among the few existing business surveys on European intangible assets, and it encompasses R&D, organizational capacities, and information and communication technology (ICT).[3] The Globalinto survey is aimed at expanding the current understanding of businesses' expenditures on intangible assets. The survey improves the microlevel measurement of intangibles and reveals their impact on economic and innovation performance at the enterprise level. Piekkola (2024) The Globalinto survey offers insights into the perceived impact of intangibles (ICs) on sales and profit margins, including profit margins from intangibles. The research period includes the COVID-19 period of 2019–2020, and the survey offers insights into how firms reacted to COVID-19 in regard to employment and R&D, among other areas. The survey measures other organizational capacities in addition to R&D that enable the adaption of higher-yield activities to internal and external circumstances (Teece et al. 1997). Technical progress often involves the reuse of existing innovations in new fields that requires organizational capital, while novel innovations often require engagement in trial and error (Bresnahan and Jones 2012). Mairesse and Mohnen (2010) claimed that product innovations can replace existing products, resulting in a mixed effect on sales and productivity. Agility is a measure of how

[1] KIS covers Nace transport 50–51 (aside from land), publishing 58, Motion picture 59 programming, broadcasting 60, telecommunication 61, arts, entertainment and recreation R, computer programming, consultancy 62, information service activities 63, M professional, technical and scientific activities aside from advertising and market research 73, rental and leasing activities 77, travel agencies 79, services to buildings and landscape activities 81, office administration, office support and other business support activities 82.

[2] The EU Horizon 2020 GLOBALINTO project on New Intangibles for European Growth (www.globalinto.eu) continues the FP7 INNODRIVE project, which developed the Innodrive methodology for measuring intangible assets at the firm level.

[3] Previous surveys include ONS (Office for National Statistics), Imperial College London, and NESTA (UK) Gaganan Awano et al., 'Measuring Investment in Intangible Assets in the Uk: Results from a New Survey', *Economic & Labour Market Review,* 4/7 (2010), 66–71., 2009 & 2011 Eurobarometer survey, 2013, INAPP and ISTAT (Italy), 2013 & 2020 (survey in progress).

quickly a firm can respond to such market transitions or shifts in customer preferences.

The sales fixed assets ratio (transformed here to turnover per the sum of tangible assets, R&D, and OC) is a new measure of financial allocation efficiency. Companies usually require equity financing in intangible investments (IC), while they often have to simultaneously rely on short-term debt during a period of heavy intangible investment (Arrighetti et al. 2015). Finally, the survey also provides information on how intangibles are considered to affect profit margins and sales.

The Global Intangible Assets Survey can be used to identify internal and external R&D activities based on organizational capacities, the business value of innovation, and the innovation environment. Internal (a company's own) R&D has been recognized since the work of Schumpeter (1943) as being essential to innovation activity. Firm-specific resources become diluted when firms develop an overreliance on external knowledge that is not novel and that can also be accessed by competitors (Grimpe and Kaiser 2010). R&D outsourcing also requires integrative capabilities for leveraging external knowledge (Helfat and Raubitschek 2000; Weigelt 2009).

Measuring skilled employee or intangible worker shares is a common means of evaluating the productivity of intangible labour in production function estimation (Hellerstein et al. 1999; Ilmakunnas and Piekkola 2014). We gauge the extent of human capital (HC) by comparing the significance of tertiary-educated individuals with that of R&D personnel who focus on specialized knowledge, such as internal R&D activities. The concept is that HC enables a wider variety of skilled employees in the organization and facilitates diverse patterns of interaction, which can be of assistance in expanding a company's innovation goals (Dahlander et al. 2016).

It is shown that internal R&D is related to higher productivity growth in firms with higher business value of innovation (BVI) levels, so productivity growth effects materialize when the marketed products and services have business value. R&D also does not cause fixed asset problems. Special-purpose ICT is needed for performance, but general-purpose ICT appears as a scale effect in the process of enhancing growth. During the COVID-19 pandemic, firms investing in R&D also generated high productivity growth. Growth policies still need to focus not only on R&D but also on other intangible assets, innovations, and digitalization that lead to higher BVI.

Section 2 analyses internal and external R&D, the business value of innovation, and the related literature. Section 3 describes the data. Finally, Section 4 provides the results, and Section 5 concludes this paper.

2. Literature on R&D and business value of innovation

The literature on R&D and economic growth follows the seminal work by Griliches (1979) for a review, e.g. Hall et al. (2010). R&D has been related to innovation activity in the CDM model by Crepon et al. (1998); see Mairesse and Mohnen (2010) for an overview. Internal R&D, in particular, provides firms with the absorptive capacity to use external knowledge outside of their technological unit (Cohen and Levinthal 1989). This capacity allows firms to recognize the value of new external information, assimilate it, and apply it to commercial ends. Recent studies have shown that internal R&D and external technology sourcing, such as external R&D, are likely complementary, see e.g. Hagedoorn and Wang (2012). Radicic and Balavac (2019) find the complementarity effect of internal and external R&D activities conditional on the breadth of R&D cooperation measured by the number of partners that cooperate (customers, suppliers, competitors, universities, and joint ventures). On the other hand, qualitative evidence suggests that implementing external R&D or open innovation strategies may create internal tension, as employees may perceive these changes as threatening their job security (Laursen and Salter 2006).

Cassiman and Veugelers (2006) observed that internal R&D can facilitate learning processes and improve absorptive capacity, thereby complementing the returns to R&D outsourcing. Using internal knowledge differs from opening its knowledge sourcing to partners since it is risky. External R&D requires special organizational resources, or there may be resistance to open innovations (Rosenbusch et al. 2011). Following Lokshin et al. (2008), companies can increase their share of external R&D while maintaining sufficient internal R&D to enhance absorptive capacity and experience higher productivity growth.

Audretsch et al. (2014) emphasize the complexity of R&D activities, together with the diversity of innovation strategies and growth modes, which requires a multidimensional approach to examine the contribution of innovations to firm growth. In this paper, R&D relates to firms' productivity growth in interaction with innovation's business value (BVI). The heterogeneity in BVI may be related to firm age, size, and region, and the empirical evidence shows a broad consensus regarding the fact that only a small number of firms contribute to net employment creation (Audretsch et al. 2014). Firms with high BVI are obvious candidates for growth, while BVI levels depend on the contribution of all intangibles.

A broader set of intangibles covers organizational capital and ICT. Hall et al. (2013) modelled R&D and ICT investment as input for innovation. They found R&D to be more important for innovation and ICT investment to be more important for productivity. R&D benefits from the sharing of knowledge and information through ICT. According to Hou and Mohnen (2013), R&D complements organizational capital and leads to product innovations in other companies aside from the largest firms. In the Globalinto survey, organizational capital investments per turnover relate to organization or business process improvement.

BVI may also be related to several factors beyond intangibles and knowledge sourcing. Demirel and Mazzucato (2012) found that R&D efforts depend on the persistent patenting of firms. Deschryvere (2014) applied a vector autoregression model to Finnish firm-level data and summarized the lead–lag relationship and complex comovements of R&D growth in a firm growth series. He found that only continuous product and process innovators exhibit positive associations between R&D and sales growth. Patenting and engagement in continuous innovation may be more directly related to R&D than to BVI, which would pursue growth at the expense of the efficient allocation of fixed assets.

Firms can also licence or acquire other companies to enhance their own innovation capacity. Various studies, including those by Cassiman and Veugelers (2006), Vega-Jurado, Gutiérrez-Gracia, and Fernández-de-Lucio (2009), and Berchicci (2013), have highlighted the benefits of such approaches or to open innovations in general. Audretsch and

Belitski (2020) found knowledge spillovers to be even more critical than R&D for firm productivity, but their study did not separate internal from external R&D.

Organizational agility is also important for knowledge sourcing, as noted by Piekkola (2024). Chesbrough (2003) discussed the increasing importance of external organizational knowledge sourcing (including such factors as agility), as several factors necessitate a transition from closed innovation to open innovation in the knowledge landscape. Finally, the integration of local technology units can help to improve the financial allocation of fixed assets. According to Hou and Mohnen (2013), companies that combine R&D with organizational capital can more readily realize product innovations, even if they are not among the largest firms.

External sourcing also requires cooperation and management skills within the organization. The organization needs to be alert to events in the market. Sull (2010) identified three different types of agility: operational agility, portfolio agility, and strategic agility, which we modify to organization agility and reactive agility (see data section). External knowledge sourcing is more directly related to reactive agility, which is a measure of a firm's capacity to react to market changes or shifts in customer demand.

We also measure the breadth of HC to understand the use of general knowledge rather than specific knowledge. The breadth of HC is proxied by share of university-educated employees to the total university-educated (HC) and R&D employees. This measure satisfies the statistical properties of the normal distribution better than the HC/RD employee ratio. We expect the occurrence of nonlinear effects that depend on firm size. Large firms can invest in fewer skilled R&D workers. In the survey data used, the breadth of HC in large firms half of that in SMEs. Knowledge-intensive firms can also heavily invest in HC to increase the breadth of HC. The breadth of HC is also higher in SMEs. Finally, Grillitsch et al. (2019) showed that combining knowledge bases is important for both high-growth and slow-growth firms.

3. Data and methods

The Globalinto Intangible Assets Survey was conducted in 2020–2021 as part of the Globalinto EU Horizon programme spanning seven countries (Denmark, Finland, France, Greece, Norway, Slovenia, and the UK). The Globalinto survey provided information on the role of knowledge production and diffusion in innovation, productivity, and growth (Caloghirou et al. 2024). Globalinto also includes knowledge-related and other types of factors that influence these investments and assesses their impact on enterprise (economic and innovation) performance. In addition, the survey includes questions concerning the changes in intangibles, innovations, and performance between the prepandemic period of 2019 and the pandemic period of 2020. In this section, the variables used in this study are summarized, and a glossary defining the acronyms used is provided in Table A.1 of Appendix A. Appendix A also presents the survey questions used in this study.

The Frascati manual 2015 was applied to the field of R&D. In-house R&D spending includes (1) the staff costs of all staff involved and (2) the associated costs, including the costs of facilities, overheads, and materials but excluding those of capital items. External R&D covers the costs of brought-in R&D services. This survey extends the official community innovation CIS survey in regard to providing reasons for investing in R&D. The survey also includes the dichotomous value of product, process, organizational and marketing innovations and information (Protogerou et al. 2025) and organizational capacities and analyses the ways that the pandemic affected employment growth and intangible investment (Piekkola 2024).

The Globalinto Intangible Capital CATI-type survey 2019–2020 covers 1,796 firms, and it is structured to represent a 40% share of service firms, which are primarily taken from the KIS sector. [4] The total of 1,790 firms in the estimation sample was mainly derived from Orbis data and uses a randomized sample from the manufacturing and service categories. Orbis data are the prime source for the stratified sampling of firms to be surveyed (1,584 out of the 1,790 firms). Orbis represents a significant data source for tangible assets and includes employment and sales data covering the previous 3-years. Productivity and employment growth are analysed for the period covering the 3 years prior to the Globalinto intangible capital survey. These 3 year growth trajectories are determined to a greater extent by annual growth than by idiosyncratic factors. Due to stratified sampling, one-fourth of the sampled firms are large (i.e. have at least 250 employees, which is the headcount number of full-time employees at the end of 2019). We use the OECD industry classification and typology of KIS (mainly intangible services) provided by Eurostat. All disposable records showed a burn rate of 8.4% (with 1,796 completed surveys per a sample size of 21,380). Refusals (12,898) were the primary reason for the burn rate.

The survey was undertaken in autumn 2020 and continued through spring 2021 in Finland, Denmark, France, Greece, Germany, Slovenia, and the UK (including 215 firms in small countries, 315 in France, 312 in Germany, and 312 in the UK). The average employment was 286 in services, which is higher than the 212 in manufacturing. The sample mainly consists of knowledge-intensive firms, which is the deliberate aim of services. Knowledge-intensive services (KIS) compose 30% of the sample, with R&D (Nace 71–72), OC (Nace 69,70,73), and ICT (Nace 62–63) having approximately equal shares of approximately 8% (the remaining 5% is mainly transport). Firms have a large average worker share of 59% R&D professional (university degree) workers in large firms, and 61% of the sampled firms pursue product innovations.

High-tech manufacturing represents the highest R&D share of professional (university degree) employees, at 74.2%, followed by KIS, at 56.7%. Internal R&D investment per employee is skewed toward service firms, with an average value of 50,000€; in manufacturing, the figure is less than one-third of this number, coming in at 15,000 thousand €. These results show that the basic service firm type in the sample also is the knowledge intensive firm. Basic services have the same average external R&D of 50,000 thousand € as KIS, followed by manufacturing at 25,000 thousand €.

[4] Note: We exclude agriculture (NACE A); forestry; mining (NACE B); water supply, etc. (NACE E); construction (NACE F); financial intermediation and insurance (NACE K); public administration (NACE O); education (NACE P); health (NACE Q); and nonprofit sectors (NACE Q, S, T, U, X). Intangible services include R&D M72, organizational capital M69-M70, M73 and ICT J61–62 water transport 50, air transport 51, publishing 58, motion picture 59, programming, broadcasting 60, telecommunication 61, finance 64–66, other professional activities 74, veterinary activities 75, employment 78, security and investigation 80, arts, entertainment and recreation R. Basic services cover wholesale trade 45–47, land transport 49, warehouse 52, accommodation, food and beverages 56, real estate 68, rental and leasing 77, travel agency 79.

The analysis includes the share of the turnover (S) from significantly improved products or services (business value of inventions BVI) either as an explanatory variable or a dummy variable taking a positive value. The significant improvement of products or services requires innovations for ensuring commercial, financial, or strategic success at the time of measurement. Such improvement does not necessarily require technological improvements in products and processes and rather relies on organizational innovations, design, and digitalization. BVI can also be expected to depend on performance relative to that of rivals. We include 23 industry dummies in the analyses to control for the differences in BVI depending on technology types across industries.

The most oversized expense item of ICs is labour costs, but ICs also incur many fixed costs. Thus, when a company initiates a growth path, the balance sheet figures may first deteriorate (profits increase over time while requiring high initial fixed costs). An excellent example is Nokia's announcements, under the new CEO, Pekka Lundmark, of new investments in 5G networks in March of 2021. Therefore, financiers need to look further into the innovation cycle. In the case of Nokia, the fruits of innovations should emerge in 2023 and continue onward.

Our measure of the breadth of HC is the HC/(R&D + HC) employee ratio (HC = university degree employee), which depends on the degree to which the firm relies on both specific knowledge (R&D) and general knowledge (HC). However, it also relies on the optimization of these elements, as large firms often have better HC.

We categorize organizational capabilities into organizational agility and reactive agility. Agile operations enable effective responses to a changing environment while maintaining productivity. In Mathiassen and Pries-Heje (2006), organizational agility is defined as the capacity of an organization to respond to customer requests, market dynamics, and emerging technology options, while organizational responsiveness to market dynamics is framed as reactive agility. The idea is to serve ever-smaller niche markets and individual customers without being burdened with the high cost that is traditionally associated with customization. The success of operational agility relies upon several factors, including the ability to access and analyse internal data on demand. Strategic or organizational agility also refers to the ability to detect and decisively seize a long-term opportunity, which are referred to as game changers. Organizational agility is a composite variable containing four dimensions: actively identifying the best practices in the sector, adjusting practices based on customer feedback, jointly developing innovation strategies across the enterprise's functional areas, and exchanging new ideas openly across the firm. Each of these dimensions was assessed by survey respondents on a five-point Likert scale (1 strongly disagree to 5 strongly agree). These variables have an approximately 0.3 correlation. The values of individual variables were averaged (total value divided by the number of components used) to estimate each firm's organizational agility value.

Reactive agility describes a business's ability to be resourceful, to respond quickly to changes, and to be highly adaptable (Mathiassen and Pries-Heje 2006, p. 116). It is focused on market dynamics and regulation rather than adaptability to customer requests. Reactive agility is reflected in cases where businesses constantly encounter short-term opportunities and act upon those opportunities to stay competitive. Reactive agility is a measure of the response capacity to market change (Najrani 2016). Reactive agility is also a composite variable encompassing three dimensions through the use of a Likert scale, namely, the rapid response to competitive moves, the quick recognition of market changes in the (e.g. competition, regulation, demography), and the regular consideration of the implications of changing market demands on new products and services. These variables have a high correlation with each other of approximately 0.4.

Digitalization is a log of the averaged value on a Likert scale of 1 to 5 of the past 3 years (2017–2019) to the investments made in the following innovation technologies: (1) hardware technologies, (2) digital technologies, and (3) bioinformatics-related technologies.

We apply productivity (turnover per employee) and three years of productivity and employment growth as one of several ways of assessing firm performance. Here, the use of employment is less sensitive to pandemics than that of turnover, and the growth figures are based on Orbis data, which has a lower sample of 1,296 firms. Our second firm performance measure is profit margins from intangibles, which is obtained from the following question on the Likert scale: Please indicate to what extent the enterprise has benefited from investments in intangible assets made in 2017–2019 in terms of profit margin.

Firms with a high R&D employee share are engaged in long-enduring projects with uncertain returns. R&D effort creates high fixed costs, which may inhibit new entrants (De Ridder 2024). The labour hoarding of R&D workers may also be necessary in cases where recruitment and layoff costs are high. The third performance measure, the efficient allocation of fixed assets, is captured by the transformation of fixed asset turnover (FAT) to $S/(S+F) = 1/(1+F/S)$, where S is turnover from the survey and fixed assets F covers tangibles and intangibles. FAT reveals how efficiently a company generates turnover from its existing fixed assets. Tangible assets per turnover are taken from Orbis data. Organizational capital (OC) OC/S and R&D/S ratios per turnover are directly available from the survey. The inclusion of OC and R&D increases the comparability between manufacturing and services, as services are more OC-intensive. Otherwise, the intangible investments are their turnover ratios OC/S and R&D/S ratios multiplied by the reported turnover S (missing data is denoted by a zero value). No attempt is made to evaluate stock values since the investment figures are already high (the reported OC and R&D values are about half that of the turnover in those firms that have it).

The questions phrased for internal and external R&D/S and specific and general (general purpose and databases combined) ICT are presented in Annex A.

In Table 1, it can be seen that turnover per employee is, on average, €357 thousand, where turnover represents the market sales of goods and services, including all taxes in 2019 aside from VAT. The median value is less than half €156 thousand, due to median firms having a meagre amount of €4 thousand R&D per employee and no tangible capital. On average, firms spent €34.9 thousand per employee on internal R&D, while external R&D spending amounted to €68.7 thousand per employee. Significantly, more firms reported pursuing internal R&D (879) rather than external R&D (357), so the distribution of external R&D per employee was skewed, with few firms showing a high external R&D intensity.

Table 1. Descriptive statistics of model variables.

Variables	Mean	Median	Std
Productivity (S/L)	357	156	2,694
FAT	0.58	0.32	0.61
Employee	242.0	60	926.0
Skilled employee share	50	10	502
R&D employee share	0.096	0.036	0.167
Internal R&D/L	34.9	0.0	177.0
External R&D/L	68.7	0.0	369.0
R&D/L	104.0	4.03	418.0
Tangible asset/L	29.60	0.00	85.10
BVI	0.15	0.05	0.23
BVI > 0 dummy	0.62	1.00	0.49
Breadth of HC, SMEs	0.58	0.67	0.38
Breadth of HC, large firms	0.19	0.00	0.36
Digitalization (scale 1–6)	1.61	1.33	0.73
Special ICT	0.28	0.00	0.45
General ICT	0.25	0.00	0.43
Reactive agility	14.40	14.0	2.9
Organizational agility	11.20	11.0	2.4
Pandemic: Employment change 2020 *versus* prepandemic 2019	0.065	0.000	0.135
Pandemic: R&D change 2017–2020	−0.020	0.000	0.272
Pandemic: Development of tailored solutions	0.364	0.000	0.481
Productivity growth 2017–2020	0.046	0.015	0.150
Employment growth 2017–2020	0.051	0.018	0.136

1,790 observations, except 759 for productivity growth and 275 for employment growth. Turnover, intangibles in thousand €. L = employee, Std = standard deviation, Obs = observations.

In Table 1, the breadth of HC, measured as the ratio of HC to R&D and HC employees, was found to be 0.58 for small and medium-sized enterprises (SMEs) and 0.19 for large firms. Approximately 555 firms in the survey reported no R&D or organizational capital (OC) but were still included (with log value equal to zero) as benchmark firms. Half of these firms reported having product or process innovations, which is not significantly lower than the firms with R&D or OC. SMEs tend to have a more extensive pool and a better breadth of HCs, while large firms can better focus on R&D.

Approximately one-third of firms had developed tailored solutions for customers, while the mean decrease in the number of employees in 2020 relative to the prepandemic 2017 was approximately 2%. The survey found that the mean value of the FAT ratio was 0.52, with a median value of 0.26. Skewness was low at 1.0 and increased to 2.6 when the fixed assets included intangibles. Last, changes in R&D employment growth due to COVID-19 were highly variable, and they were set to zero when this data was missing.

4. Results

The models used in Tables 2-4 fit well according to the linktest. In other words, the squared predicted value coefficient is nonsignificant when any of the explained variables listed in Tables 2-4 are compared to the predicted value and its square. The only exception is when the log of R&D per employee is studied, which can be found in Table 2 below. A more fit model would consider intangibles as a whole. Table 2, in the first column, reports the maximum likelihood Tobit model for the log of R&D/L and then presents the more fit model for BVI that uses a lower limit of 0 in the second column. The explanatory factors include a dummy for intangibles benefitting profit margins, the breadth of HC, the log of digitalization, and organizational and reactive capabilities (agility) to any extent. The control variables include size (employee log) and country.

In Table 2, research and development intensity (R&D/L) and the business value of innovation turnover share (BVI/S) are both positively related to IC profit margins. Digitalization, special purpose information and communication technology (ICT), and firm size all positively impact R&D and BVI/S. Additionally, R&D/L exerts a direct effect on BVI/S. The breadth of HC has a distinct negative relationship to R&D and BVI/S. The negative effect of the breadth of HC suggests that firms benefit by focusing their internal knowledge sourcing on R&D. At the same time, further analysis shows that a certain share of HC is necessary to keep the firm productive, but likely at the cost of profit margins.

The development of tailored solutions positively affected R&D intensity and BVI/S during the pandemic. During that time, firms focused on creating customized solutions that may have involved R&D. An increase in R&D due to the pandemic rather loosely relates to a firm having high levels of R&D/L (during the pandemic, firms reported a decrease in R&D/L investment on average, but with high heterogeneity, as seen in Table 2). Both R&D intensity and BVI/S are apt measures of the degree to which a firm is knowledge-intensive and applies knowledge sourcing through the use of digitalization and developing tailored solutions. Knowledge spillovers are another important factor in this, but they are beyond the scope of this paper (Audretsch and Belitski 2020). Unfortunately, the survey contains no dynamic data regarding the persistence of innovations that could be used to distinguish between R&D intensity and BVI/S. The main difference is that BVI/S is used to measure the benefits of all intangibles, while R&D intensity is more clearly related to patenting (which is not shown here). The other important difference is that R&D intensity increases with increasing firm size. In the following, the inclusion of BVI is important since it relates to all intangibles and its use improves our model's fitness.

Table 2. Tobit models of interrelations of R&D/L and BVI.

	Log of R&D/L	BVI/S
Log of R&D/L		0.005**
		(0.002)
IC improving profit margins dummy	1.547**	0.111***
	(0.497)	(0.02)
Breadth of HC, SMEs	−13.784***	−0.143***
	(0.958)	(0.04)
Breadth of HC, large firms	−13.835***	−0.106*
	(1.216)	(0.051)
Log of digitalization	3.377***	0.048*
	(0.541)	(0.022)
ICT special purpose	1.544**	0.042*
	(0.479)	(0.02)
ICT general (general purpose, database)	0.516	−0.012
	(0.512)	(0.021)
Log of L (employee)	1.088***	−0.022
	(0.283)	(0.012)
Organizational agility	0.186	0.02
	(0.345)	(0.014)
Reactive agility	−0.113	0.009
	(0.308)	(0.013)
Pandemic: Development of tailored solutions	1.429***	0.071***
	(0.428)	(0.017)
Pandemic: R&D change %	−4.345***	−0.031
	(0.575)	(0.025)
Constant	−1.72	0.025
	(3.22)	(0.118)
Observations	1790	1790
Log-likelihood	−3735.0	−745.6
LR(C^2)	653.8	229.2
Breusch–Pagan test for heteroskedasticity *P* value	0.000	0.000
R-Squared (Pseudo ordered logit)	0.080	0.133

Tobit estimate with lower limit 0. Controlling variables include 23 industry and 7 country dummies. ***significant at the 1% level **significant at the 5% level, and *significant at the 10% level.

Table 3 displays firm performance as measured in three distinct ways. The productivity measure reflects turnover per employee. Total factor productivity is not used, as tangible investments are generally known to be imprecisely measured and to rely on different data sources than Orbis. The second model is a generalized logit estimation derived from the Likert scale responses regarding the perceived effect of intangibles on profit margins. The third performance measure is related to financial efficiency as measured by the sales total asset ratio. Total assets are the sum of ICs as taken from the survey and the fixed assets derived from Orbis data. Table 3 displays the results.

Research and development, both internal and external, have been shown to positively impact all performance measures, as demonstrated by Piekkola (2024). In Table 3, internal R&D significantly affects productivity, which increases in value if the firm holds any inventions of business value (the BVI dummy is positive). Audretsch and Belitski (2020) argued that R&D affects labour productivity not only through innovations but also by facilitating knowledge exchanges such as collaboration with external partners and knowledge spillovers from other industry firms. The knowledge spillover effects are transmitted here from other channels, such as digitalization and organizational capabilities that are related to reactive agility.

R&D absorbs skilled employees away from other value-creating activities, especially in SMEs. The analysis suggests nonlinearities in the R&D and HC breadth trade-offs. Large firms can afford a lower breadth of HC; the productivity effects are more significant than those in SMEs. In Table 3, the breadth of HC can be seen to also be critical for higher productivity.

External R&D positively affects firm performance in all three ways: through productivity, through IC profit margins, and through FAT. Therefore, the R&D effort and breadth of HC should be combined with external R&D to realize the optimal allocation of resources. Digitalization significantly improves profit margins from intangibles, where special purpose ICT is necessary. Brynjolfsson et al. (2010) show that the variety of products available and purchased online is higher than that offline using data from a retailer that uses both online and offline channels. Calvino et al. (2022) found that R&D expenditures help to gain the full potential of digitalization. Digital technologies that increase the likelihood that R&D activities result in a new patent.

An important finding here is that organizational agility decreases productivity while exerting a positive effect on profit margins from intangibles. Reactive agility is more consistent than organization agility in improving both productivity and profit margins derived from intangibles. This situation can change when the target is the promotion of employment growth. Using the same data, Bonfour et al. (2023) considered the causal relation of intangibles to improvements in strategic agility. Their concept of agility loosely corresponds to the reactive agility measure used here, but it also includes responsiveness to customer needs. Our results show that organizational agility plays a similar role.

Table 3. Productivity (OLS), profit margin (generalized ordered logit), and fixed asset turnover (FAT) (Tobit) estimates.

	Productivity	Profit margin from IC	FAT
BVI/S dummy	−0.195***	0.330**	−0.042
	(0.057)	(0.12)	(0.037)
Log of internal R&D/L	0.107***	−0.043	0.076***
	(0.022)	(0.046)	(0.012)
Log of internal R&D/L, BVI dummy	0.062*	0.047	0.008
	(0.026)	(0.053)	−0.015
Log of external R&D/L	0.051***	0.073**	0.121***
	(0.011)	(0.024)	−0.006
Breadth of HC, SMEs	0.528***	−0.440*	0.056
	(0.104)	(0.217)	−0.061
Breadth of HC, large firms	0.798***	−0.206	−0.072
	(0.131)	(0.272)	(0.077)
Log of digitalization	−0.092	0.771***	0.041
	(0.053)	(0.116)	(0.032)
ICT special purpose	0.019	0.404***	0.019
	(0.047)	(0.095)	(0.027)
Tangible asset/L	0.001***	0.000	
	(0)	(0.001)	
Log of L (employee)	−0.126***	−0.201**	0.052**
	(0.031)	(0.065)	(0.018)
Organization agility	−0.041***	0.110***	0.015**
	(0.009)	(0.02)	(0.005)
Reactive agility	0.045***	0.087***	−0.001
	(0.011)	(0.023)	(0.007)
Pandemic: Employment change %	−0.742***	−0.035	−0.035
	(0.163)	(0.319)	(0.093)
Pandemic: R&D change %	0.103	0.03	−0.022
	(0.069)	(0.14)	(0.037)
Constant	5.310***	0	−0.103
	(0.205)	(0)	(0.123)
Log-likelihood	−2 372	−2356.2	−1045.8
LR(C^2)		375.0	613.5
R-Squared (Pseudo ordered logit)	0.166	0.074	0.227

Column 1 shows OLS. Column 2 shows the generalized ordered probit and heterogeneous technology types. Column 3 shows the tobit estimates with the lower limit of 0. Includes 23 industry and seven country dummies. ***significant at the 1% level **significant at the 5% level, and *significant at the 10% level.

Table 4. OLS for annual productivity and employment growth over 3 years, 2017–2020 and 2019–2020, %.

	Growth three years 2020–2017	
	Productivity growth	Employment growth
Log of internal R&D/L	−0.003	−0.001
	(0.004)	(0.002)
Log of internal R&D/L, BVI/S	0.026**	0.013
	(0.009)	(0.007)
Log of external R&D/L	0.001	0.000
	(0.003)	(0.002)
Breadth of HC	−0.01	−0.021
	(0.027)	(0.018)
ICT general (general purpose,	0.026*	0.018*
database)	(0.012)	(0.008)
Organization agility	0.000	0.013*
	(0.009)	(0.006)
Reactive agility	0.011	−0.008
	(0.008)	(0.006)
Pandemic: Employment change %		0.119***
		(0.026)
Pandemic: R&D change %	0.037*	
	(0.017)	
Observations	755	−0.061
R-Squared	0.100	0.072

Includes seven country dummies and constant. ***significant at the 1% level **significant at the 5% level, and *significant at the 10% level.

R&D/L, HC breadth, and organizational agility all improve the efficient allocation of fixed assets, and thus of FAT. This gives a strong indication that knowledge firms with a sufficient breadth of HC and organizational agility to avoid any high fixed cost problems arising from intangibles invest in R&D. The fixed assets allocation if such firms are efficient. An essential point in the analysis is that we control BVI, which, according to the estimation results, is unrelated to FAT. A possible explanation for this is the correlation between BVI and a rapid growth phase (as shown below in Table 4), during which companies can engage in a more secure form of 'overinvestment' in R&D and tangible assets. Finally, productivity is negatively related to high employment, as driven by the COVID-19 pandemic. The sudden increase in demand for certain goods due to the pandemic may have increased production costs.

Table 4 relates R&D to annualized productivity and employment growth during the period of 2017 to 2020, where employment growth can indicate a high-growth firm. The analysis was limited to 748 firms for productivity growth and 1,267 firms for employment growth since the Orbis data were only sometimes available. Four observations were dropped from the analysis based on outlier analysis to identify observations that can potentially influence the regression coefficient estimates. VIF analysis shows that the industry dummies used are unstable, and hence they are omitted, while the remaining variables are stable and thus retained.

Investing in internal R&D profoundly impacts productivity or employment growth, but only when combined with a high BVI. Bauer and Genty (2022) instead found strong direct effects on employment growth. Table 4 also shows that firms that increased their levels of R&D investment during the COVID-19 pandemic experienced higher productivity growth. While external R&D is positively correlated with productivity (see Table 3), it does not significantly impact a firm's growth orientation. Thus, BVI and internal R&D are critical to the identification of higher productivity growth potential.

Notably, Table 4 shows that firms that increased employment during the COVID-19 pandemic were also those with high average growth in employment from 2017 to 2020. However, in Table 3, we can see that low-productivity firms were more likely to increase their employment due to the pandemic. More significant growth in productivity and employment relates to the utilization of general ICT, such as general-purpose office applications and databases. As the products and services are now prepared for marketing, the company requires more general ICT to scale and less specialized ICT for innovative solutions. While reactive agility reflects high productivity, it is not a characteristic of the high-growth phase.

Finally, the breadth of HC did not significantly impact the growth in productivity and employment, and reactive agility is unrelated to productivity growth. Rather, organizational agility is related to higher employment growth.

5. Conclusion

This paper delves into the impact of internal and external R&D on firm performance, finding internal R&D to be the core element, although external R&D also has an important role to play. It is essential to note that internal R&D should be combined with a high business value of inventions to result in productivity growth. Hence R&D, as does BVI, is related to initiating a rapid growth phase. Internal and external R&D improve productivity and, thereby, enhance the financial allocation of fixed assets. During the COVID-19 pandemic, firms that invested more in R&D also generated high productivity growth.

Complementing the relationship between internal and external R&D is dependent on the value of internal R&D through BVI. In firms with low BVI, complementarity can be absent. In contrast to the literature, it is not the level of R&D but rather its capacity to create business value through innovation that drives complementarity. External R&D has a more independent effect on productivity and profitability, but it does not create growth.

The paper reveals context-dependent results, as digitalization, special purpose information, and ICT are positively related to both R&D and BVI as well as having an independent positive effect on profitability. General-purpose rather than special-purpose ICT is related to productivity and employment growth. The scaling effects of general-purpose ICT arise from a broader use of office applications and databases.

We also show an important role for organizational capabilities. Reactive agility is linked to higher productivity and profit margins from intangibles, as is the case in Bounfour et al. (2023). Digitalization and reactive agility are important for good performance because of their positive relation to R&D and BVI. Organizational agility improves profitability and employment growth. Piekkola (2024) has already indicated that the benefits of organizational capital and agility include better management of all intangibles and the improvement of employment growth. General-purpose ICT and organizational agility are thus important in growth processes.

The breadth of HC positively affects performance but does not lead to higher productivity or employment growth. One reason for this may be that as firms mature, growth opportunities from innovation arise. It is noteworthy that SMEs require a higher HC/R&D employee ratio than large SMEs, which can limit their growth.

Our analysis reveals only a limited need to support R&D, as R&D does not cause excessive financial costs. Haskel and Westlake (2022) rather emphasizes the risks associated with innovations, given the potential of sunk costs with limited resale value in the event of business failure. Various characteristics of intangible assets still justify the need for public sector interventions. According to Gadepalli et al. (2023), policy-makers must acknowledge the unique characteristics of intangible assets when developing initiatives to benefit from their use and advancement. Intangibles possess both synergies and nonseparability properties that make them challenging to replicate, which can give a firm an edge in the competitive landscape. Intangibles are known to generate synergies when combined with other assets and with BVI.

However, the nonrival, partly excludable, and transferable nature of intangibles also prompts knowledge spillovers and restrains firms from fully leveraging their intangible holdings. Public subsidies for R&D projects that generate significant spillovers can lead to great benefits due to internal R&D serving as an important source of growth even after accounting for BIV. However, these subsidies may crowd out private R&D investment especially in the same industry (Nieto and Quevedo 2005), or in the long run (Takalo et al. 2013).

Growth policies should focus on R&D and other intangible assets, innovations, and digitalization, particularly those that lead to high BVI. Therefore, according to Piekkola (2024), public policy should support the use of a wide range of intangibles, thus also ensuring efficient financial allocation of fixed assets, including that of intangibles.

Conflict of interest: None declared.

Funding

This study was funded by the EU Horizon 2020 GLOBALINTO project for the years 2019–2022 [grant number 822229]. The project's title is 'Capturing the value of intangible assets in micro data to promote the EU's growth and competitiveness.'

Data availability

Globalinto intangible capital survey over seven European countries is done on the condition that it cannot be disseminated.

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Science and Public Policy, 2025, 52, 950–959
DOI: https://doi.org/10.1093/scipol/scaf045
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