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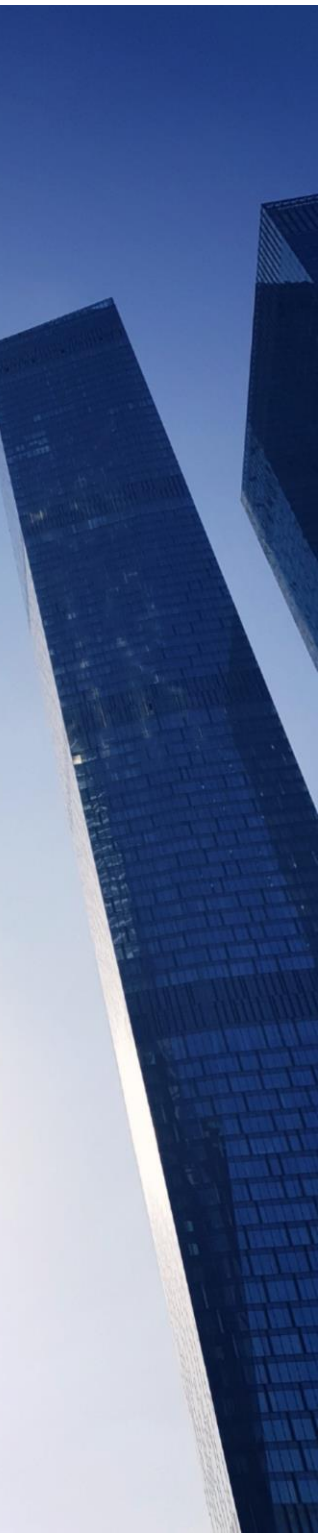
ANNUAL REPORT ON EUROPEAN SMEs 2018/2019

Research & Development and Innovation by SMEs

Background Document



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1 Introduction

The present Background Document is a companion document to the Annual Report on European SMEs 2018/19 – Research & Development and Innovation by SMEs.

The Background Document presents:

- the findings of a review of the literature review on research & development and innovation (R&DI) by SMEs
- ten case studies highlighting the issues and challenges faced by innovating[1] SMEs and the various types of public support received or sought by these SMEs
- the results of a cross-section analysis explaining differences over time in R&DI activity by SMEs across Member States at a macro level
- the results of several firm-level (i.e. micro) econometric analyses of the drivers of SME R&DI activity using:
    - the micro data of several Surveys on the access to finance of enterprises (SAFE)
    - the micro data of the 2016 Innobarometer
    - the micro data of the 2014 Community Innovation Survey (CIS)

[1] Disclaimer: For the purposes of this document, the term "innovating company" refers to the companies that have introduced a new or significantly improved product or service to the market; a new or significantly improved production process or method; a new way of selling goods or services, or a new organisation of management. The data comes from the companies' self-assessment of relevant activities. Innovating companies come from all sectors and are not limited to the disruptive or digital sectors. Non-innovating companies are not precluded from introducing innovations in the future.

2 Key findings of the recent literature on SMEs and R&DI

2.1 Key facts on R&D and Innovation

The term R&D is generally defined as "creative and systematic work undertaken in order to increase the stock of knowledge – including knowledge of humankind, culture and society – and to devise new applications of available knowledge" (OECD, 2015, p.44). A business innovation is "a new or improved product or business process (or combination thereof) that differs significantly from the firm's previous products or business processes and that has been introduced on the market or brought into use by the firm" (OECD, 2018a, p.68).

A firm invests in R&DI expenditures if it perceives an opportunity to make a profit by developing and implementing new products and/or processes. These opportunities are varied: A firm can, for example, build an advantage over its competitors by bringing innovative products to the market, it can acquire patents for these products, it can reduce production costs through efficiency gains and it can enhance its reputation by being perceived as an innovator. Finding robust evidence of a positive and significant impact of R&DI on productivity at the firm level, the existing economic literature emphasises innovation as a key mechanism for businesses to successfully compete with others (see, e.g., McCann and Ortega-Argilés, 2016).

Neoclassical growth models identify investments in R&DI as a key factor of technological progress and, thus, as the engine of economic long-term growth and development (Romer, 1990; Grossman and Helpman, 1991; Aghion and Howitt, 1992). Reflecting the importance of R&DI, the latter has been placed at the heart of the "Europe 2020" strategy – the EU's agenda for "smart, sustainable and inclusive growth" (European Commission, 2010).

The need for government intervention to stimulate R&DI investments

When a firm decides how much to invest in R&DI it weighs investment costs against the expected private profits it will reap from the new idea or product. In contrast, the overall social benefits from RD&I exceed private profits as they take into account the diffusion of new knowledge and technology to other firms and society as a whole. As private profits that the firm reaps from an innovation are smaller than the social benefits, firms invest less in R&DI than what would be optimal from a social perspective – causing a so-called „market failure".– (Hall et al, 2010). To mitigate this market failure, governments use different policy instruments, e.g., tax incentives and subsidies, to stimulate private R&D spending (OECD, 2018b). There exists a vast literature which examines the impact, efficiency and effectiveness of different R&D policy instruments (see, e.g., Hall and Van Reenen, 2000; Hünermund and Czarnitzki, 2016; McCann and Ortega-Argilés, 2016; Radicic and Pugh, 2017; Atkeson and Burstein, 2018; Petrin, 2018).

The contribution of SMEs to innovation

SMEs play a critical role for technological change and, thus, in the innovation system, among other, only because they represent a large share of economic activity in most economies . They introduce advances in products, methods of production and management processes by making breakthrough innovation themselves or by adopting incremental innovations generated by large firms (OECD, 2010). Because of constraints in internal resources (given their size) as well as external resources (due to market failures), it is often argued that SMEs should be particularly targeted by public support for R&DI (Okamuro et al., 2019). SMEs in OECD economies are, on average, less innovative than large firms: across OECD countries the median share of SME business R&D is 35%. At the same time, some SMEs are among the most innovative firms – especially in science-driven sectors like biotech and nanotech (OECD, 2018b). These firms exploit technological or commercial opportunities that have been neglected by larger firms (Talbot, 2018).

2.2 Theoretical framework: Determinants of R&DI investments

2.2.1 Firm size and market power as key R&DI determinants in Schumpeter's models

In the economic literature, there is a long debate tracing back to the famous Austrian economist Schumpeter about the role of small and large firms in technological progress and innovation.

Schumpeter's early work suggests that SMEs are likely to be the source of most innovations (Schumpeter, 1934). He argues that small firms should be in a better position to innovate due to their flexibility while large firms might get trapped by bureaucratic structures. Schumpeter initially saw entrepreneurs as playing a key role in challenging incumbent firms by introducing new inventions which render current technologies and products obsolete and, thus, replacing obsolete firms with new ones in a process of "creative destruction".

Witnessing the growing economic power of large firms, however, Schumpeter changed his view later on (see Schumpeter, 1942). He noted that larger firms with some degree of monopolistic power could have an advantage in developing innovations as they can capture the returns to innovation without being imitated by rivals. Moreover, he (1942) acknowledges that small firms lack the capital resources available to their larger counterparts. Both internal and external capital constraints are severe for SME R&DI activities. Due to high uncertainty about the outcome ot the R&DI activities, information asymmetry and lack of substantial collateral, SMEs find it difficult to obtain external financing for R&DI projects (Hall and Lerner, 2010; Hottenrott and Peters, 2012; Mancusi and Vezzulli, 2014, Ullah et al., 2018). More generally, large firms might benefit from cost advantages in R&DI projects due to economies of scale and scope (Vossen, 1998).

To summarise, smaller firms are typically said to have "behavioural advantages" in terms of rapid decision-making, willingness to take risks, entrepreneurial dynamism and motivation, as well as flexibility in responding to new market opportunities. In contrast, large businesses haver some advantages deriving from economies of scale and the availability of financial and technological resources (Vossen, 1998).

Empirical evidence on the relationship between a firm's size and investments in R&DI is mixed: While up to the late 1980s, the pioneering role of large firms with their R&D units was stressed by academic researchers and policymakers (Ortega-Argilés et al., 2009), more recent empirical evidence provides many examples of highly successful innovations stemming from SMEs which have revolutionised entire industries – a clear illustration is provided by Silicon Valley which is as fertile ground for start-ups and "hotbed for innovation" (Audretsch, 2002; Bresnahan and Gambardella, 2004).

Nowadays it is widely acknowledged that additional factors besides firm size influence the extent of RD&I undertaken by a firm. However, there is considerable debate about which determinants play the most important role for RD&I activities (for a literature survey , see Becker, 2013).

2.2.2 Other fundamental R&DI determinants

The major factor types driving R&DI activities which have been identified and analysed in the academic literature are individual firm characteristics (e.g., internal finance and sales) and industry characteristics (Becker, 2013), competition in product markets (for a literature survey, see Halpern and Muraközy, 2015), government policy measures (the theoretical motivation for R&D tax credits and their impact emerged from Arrow's seminal piece "Economic Welfare and the Allocation of Resources for Inventions" published in 1962) as well as location and resource related factors (for recent evidence from Europe, see Prenzel et al., 2018).

2.3 Empirical research: R&DI trends

2.3.1 The relevance of a firm's size as determinant of RD&I

Empirical evidence on the relationship between a firm's size and investments in R&DI is mixed: Comanor (1967) analysed US data from 1955 to 1960 and found that R&D rose more than proportionally with firm size. Scherer (1965) evaluated US invention patents and found that innovation activity increased more than proportionally with size up to a certain threshold, whereupon the relationship became basically proportional. The US economy in the 1950s was dominated by large corporations able to exploit large economies of scale in production, distribution, management and R&D (Chandler, 1977). During this period SMEs participated only to a limited degree in innovation in the US economy (Acs and Audretsch, 1990; Scheirer, 1991).

Even though the degree of concentration in R&D spending remains high – most visibly in the high-tech biopharma and digital sectors (Veugelers, 2018) – the contribution of SMEs to innovative activities has increased over the last decades (Acs and Audretsch, 1993 and 2005; Scheirer, 1991). In line with the modern view that factors other than a firm's size determine R&DI investment, Cohen et al. (1987) found that the size of the firm itself only had a negligible positive effect on R&D intensity, and after controlling for the industry in which the firm is active, the size effect disappeared.

2.3.2 Reasons why SMEs have become critical innovation players over the last decades

The contribution of start-ups and SMEs to innovation has increased in recent decades due to changes in the way innovation occurs in the economy (OECD, 2018b). The changes are primarily caused by the shift from the "Managed Economy" to the "Entrepreneurial Economy" which is increasingly dominated by knowledge as major production factor (Audretsch and Thurik, 2004; Thurik, 2009). In the "Managed Economy", science and large firm R&D were key. In the "Entrepreneurial Economy", entrepreneurship is one of the foundations of innovation (OECD, 2010).

Much of one of the main advantages that large firms enjoyed in the "Managed Economy" – namely producing standardised products in large volumes at low cost – has disappeared. The factors explaining this development are[2]:

i. A massive shift from manufacturing to services brought with it new types of non-technological innovation that reduces the significance of economies of scale in R&D..
ii. The increased taste for variety is associated with the emergence of multiple niche markets, which new and small firms are quick to fill. Quickly changing consumer preferences, increased competition and new technologies have reduced product life-times, demanding more rapid creation of products and their more rapid destruction.
iii. New technologies allow small players in many industries to produce small batches of goods as efficiently as large firms once produced large batches. Advances in technology thus allow firms to come from nowhere and turn entire markets upside down.

Improvements in information and new communications technologies (linked with globalisation) also play an important role as they facilitate regional and international collaborations between universities, research organisations, customer, supplier and competitor firms and consumers. Rogers (2004) points out that SMEs may rely more heavily on external knowledge networks as an input to innovation than large firms.

Furthermore, new information technologies foster the development from closed to open innovation (OI). Innovation today involves going beyond exclusive reliance on internal ideas from within a firm (closed innovation) to the usage of multiple external sources to drive innovation (Chesbrough, 2006; O'Sulllivan et al., 2013; Warwick and Nolan, 2014). There exists considerable evidence that suggests that a major comparative advantage of SMEs over their larger competitors may be their ability to efficiently exploit knowledge created outside the firm (Nooteboom, 1994; Rothwell and Dodgson, 1994; Audretsch and Vivarelli,

[2] See OECD (2010).

1996; Lasagni, 2012). Spithoven et al. (2013), using EU data covering the period 2002-2004, point out that SMEs are more effective than large firms in using different OI practices simultaneously when they introduce new products on the market.

Vahter et al. (2013) analyse the Irish manufacturing sector using the panel data from 1994-2008 and conclude that small firms can gain significantly from adopting an OI strategy. Modern technologies facilitating information sharing and productive R&D collaborations have thus put an end to the "knowledge monopolies" of large firm R&D laboratories and opened up innovation to SMEs that participate in (global) knowledge transfer networks with universities, large firms and other players.

Another major change which the entrepreneurial economy has brought about is the increased importance of flexibility and enterprise agility. Innovation in the knowledge economy is results from creativity and the unexpected[3], which is "more likely to be found in new and small operations than in the systematic research that characterises large firm R&D laboratories" as large firms often encounter systemic problems in transforming their extensive knowledge base into innovations (see Murray and Worren, 2010).

Radical innovations often stem from small businesses that successfully exploit their flexibility and ability of working outside of dominant knowledge paradigms. This holds in particular for science-driven sectors such as, for example, biotech and nanotech. For example, SMEs account for about 20% of patents in biotechnology-related fields in Europe. "SMEs also constitute the bulk of high-growth firms", which are innovative firms that grow fast over a short period of time "thanks to disruptive changes in their 'business as usual' practices" (OECD, 2018b, p.5).

2.3.3 Heterogeneity of SMEs' RD&I behaviour

The economic trends and technological developments described above have contributed to the emergence of an environment in which entrepreneurship and SMEs have moved up on the policy agenda. SMEs which react fast to changing market niches and exploit technological or commercial opportunities can be found among the most innovative firms. A KfW study published in 2017 on innovation in German SMEs shows that innovative SMEs are investing more and more in innovation activity (Zimmermann, 2018).

At the same time, SMEs still are, on average, less innovative than large firms. Across OECD countries, the median value in the national SME share of business R&D is 35% (OECD, 2018b).

A 2017 KfW report on German SMEs titled "Trend towards fewer innovators continues" states that, while those SMEs, which are still innovators, are increasing their investments in innovation activities, the proportion of innovative SMEs in Germany has dropped by more than a third from the peak reached in 2004/2006 (Zimmermann, 2018). The factors which are likely to have contributed to the long-term trend of fewer innovative SME include low start-up activity, growing price competition, relatively weak sales expectations, political imponderables, and continuing difficulties in obtaining innovation funding (Zimmermann, 2017). Given that German "SMEs seem to have retreated from innovation and R&D", a study conducted by the Fraunhofer Institute for Systems and Innovation Research (using German firm data from 2001 to 2013) sees "a strong need to take measures against the concentration of innovation and R&D activities in larger firms" (Rammer and Schubert, 2016, p.23).

2.3.4 Effectiveness of policy instruments

A substantial body of empirical studies seeks to understand the causal effect of policy intervention on firms' R&DI behaviour, its cost effectiveness and the macroeconomic impact.

[3] See OECD (2010, p.27).

The literature review by Petrin (2018) reveals a substantial heterogeneity of empirical studies with respect to the periods analysed as well as to the level of aggregation and data used. Moreover, studies differ in geographical scope, the measurement and definition of variables such as R&D expenditure and the type of government support measures being assessed. "For this reason it is difficult to arrive at any firm conclusion regarding the [...] impact and effectiveness of government support for R&D and innovation." (Petrin, 2018, p. 28). Moreover, the "degree and magnitude of the effect vary with firm size and nature of firms, generosity of support, industry studied, the tax system etc." Nevertheless, Petrin concludes that the evidence accumulated over the period 2003-2017 suggests that direct government support (such as grants, subsidies and loans) may positively impact innovation outcomes such as increased number of patents, sales of new product and introduction of new processes.

A greater impact on firm innovation output is generally found for SMEs (What Works Centre for Local Economic Growth, 2015). Most studies reviewed show an increase of firms' R&D expenditure due to R&D tax incentives (see, e.g., Westmore (2013) who evaluates OECD country-level data from 1983 to 2008 and finds a positive effect of R&D tax incentives on the level of R&D).

Evidence also suggests that the effect is the highest for SMEs, young firms and firms with high R&D orientation (see, e.g., the meta-regression conducted by Castellacci and Lie (2015), Cappelen et al. (2012) who review Norwegian data and Dechezlepretre et al. (2016) who focus on UK data).

2.3.5 R&D outsourcing

As mentioned before, innovation is essential for the survival of firms in highly competitive industries. R&D outsourcing, that is the purchasing of R&D or technological knowledge from external providers, can be an important way to stimulate or complement a firm's innovation (see Contractor et al., 2010; Nieto and Rodríguez, 2011; Berchicci, 2013; Bertrand and Mol, 2013). The global R&D outsourcing services market is expected to grow at a compound annual growth rate of 8.31% during the years 2017-2021 (HTF MI, 2017).

Particularly for SMEs, research cooperation and R&D outsourcing can offer possibilities to complement the often limited internal research resources (Love and Roper, 2015). OI helps smaller firms share risk and match innovation resources flexibly (Van de Vrande et al., 2009; Vahter et al., 2013). Toedtling et al. (2011) find that the potential for OI in Austrian SMEs is the greatest when SMEs are operating in metropolitan regions with strong industrial and innovation eco-systems where potential innovation partners are numerous and easily accessible.

However, it is not only SMEs that use R&D outsourcing as a strategy to stay competitive in a world of rapidly growing knowledge, increasingly sophisticated technologies and an unstable economic environment. When large firms outsource R&D activities they may benefit from better access to scientific talent and expertise as well as increased flexibility (Narula, 2004). The pharmaceutical/biotech industry has the highest levels of R&D outsourcing across hi-tech industries – some large pharmaceutical firms report that 40% or more of their R&D spending will be outsourced to academic and private contract research organizations in the near future (PwC, 2014). Some even argue that "managing outsourcing has become the number one challenge for many pharmaceutical R&D executives" (Paik et al., 2017, p. 305). While R&D outsourcing may have many advantages for a firm, a 2014 study (using survey data from a wide range of German firms) by the Center for European Economic Research notes that the cost savings that come from outsourcing R&D can easily be overshadowed by the added complexity to manage the process (Baier et al., 2013). The authors argue that "smaller firms find it easier to deal with the management complexity induced by geographical dispersion of innovation activities because of their greater flexibility" (p.1).

Phillips and Zhdanov (2013) note another recent trend which might contribute to a growing concentration of R&DI activities in large firms. Instead of undertaking R&D in-house, large firms can optimally outsource R&D investment to small firms in their industry and then acquire those that successfully innovate.

2.4 Key takeaways

- Firms usually invest in R&DI to increase their profits or to remain competitive.
- While SMEs are typically said to be more flexible in responding to new market opportunities than large firms, they often have to deal with limited financial, human and technological resources when organizing and conducting their R&DI activities.
- SMEs in OECD economies are, on average, less innovative than large firms. However, in recent decades, their contribution to innovation has increased due to changes in the way innovation takes place: Increasing niche market demand, shorter product life times and changing technologies have enabled SMEs to strengthen their comparative advantages and reduced the structural disadvantages due to resource constraints and limited ability to reap economies of scale.
- There exists a substantial body of academic literature on the impact of policy interventions on firms' R&II activities which suggests a positive impact of a) public support which is higher for SMEs relative than for large firms (see Petrin, 2018)) b) R&D outsourcing (SMEs benefit from risk sharing and can overcome internal resource constraints when outsourcing R&D (Love and Roper, 2015)).

3 Issues and challenges faced by SMEs when undertaking R&DI – 10 case studies

The present chapter presents 10 brief case studies of innovative SMEs and the challenges they faced.

3.1 Case study 1: Norsepower (Finland)

3.1.1 Introduction

Norsepower's story illustrates the importance of European and national financial support for start-ups investing in Research, Development and Innovation (R&DI). For the company Norsepower, Horizon 2020 and Business Finland a local help scheme for R&DI were used as the initial funds for investing in innovation, and allowed the company to grow and expand globally.

Tuomas Riski founded Norsepower in Finland in 2012, with the goal to reduce the environment impact of shipping, by providing efficient, easy to use, and reliable auxiliary wind propulsion for ships. This was possible through the Rotor Sail Solution Technology, a wind propulsion system that was created for large ships. Norsepower is now the market leader in mechanical sales for large ships.

3.1.2 RD&I activities

Research, development and Innovation activities began in 2012 and were the starting point for Norsepower, as the company started with the commercialisation of the new mechanical innovative product. Norsepower is a single product company. The R&DI activities are based on an externalisation model.

In the early phases of development (and even now), Norsepower worked with many partners and suppliers, who cooperate with Norsepower on R&DI activities. The company first designed its RD&I strategy and then developed partnership agreements with other partners to enhance their research activities. All the R&DI activities are managed in Finland. The company also owns all of the intellectual property rights produced by both the external suppliers and partners. Moreover, RD&I remains one of the core activities of Norsepower, with almost a third of its current employees undertaking research activities. The main focus area of the company is now its accelerated growth, which does not stop Norsepower from being constantly innovating and fine tuning its product.

3.1.3 Public support

The main public supports that Norsepower benefitted from were the following:

- Horizon 2020 (the biggest EU Research and Innovation programme): The initiative is supporting SMEs' innovative ideas with growth potential through two phases. The first phase is exploring the feasibility of the business idea while the second phase is developing and preparing the innovative business idea for its commercialisation. The scheme targets highly innovative SMEs with a strong ambition to develop, grow and internationalise, and also include coaching and support services. For Norsepower, Horizon 2020 was particularly helpful for the access to finance and the networking and internationalisation services.
- Business Finland (the Finish accelerator of global growth): The programme is centred on four main types of support for SMEs. Business Finland supports SMEs in their international growth, helping companies to find new partners or experts and offer funding for research, products development and other business development needs. The scheme is also supporting SMEs in their networking activities and in the creation and development of ecosystems, that provide small and medium sized companies opportunities to grow and innovate.

The supportive Finish environment for SMEs was also of great help for Norsepower. The company had their first customer in the country, before expending to the current 30 countries where they now operate.

3.1.4 Finding customers as a key growth challenge

The biggest obstacle encountered by the company has been finding pilot customers to work with. None of the programmes that they benefitted from could help them finding such customers. In addition, while the R&DI activities did not raise any particular challenges themselves, accessing Horizon 2020 funding was extremely challenging for the company and it needed three applications to finally have a succed.

3.1.5 Policy recommendations

While the company benefitted from the financial support of Finland and the European Commission, the networking and internationalization services of the schemes were also of considerable importance, according to Tuomas. Indeed, those services helped Norsepower and its team to get introduced to external R&DI, manufacturing, sales and marketing investors and partners, and to expand the company globally. Therefore, the financial support of RD&I activities for SMEs is of utmost importance but so are the networking and internationalisation services of the RD&I support schemes. The pilot customers to test the product of Norsepower have been found by the company independently of the RD&I support schemes. A lack of pilot customers slow SMEs' innovation processes as companies have challenges to test their products to better align with clients' expectations. Programmes helping SMEs to find pilot customers could thus strengthen SME's RD&I activities.

3.2 Case study 2: SunOyster Systems (Germany)

3.2.1 Introduction

SunOyster Systems GmbH (SOS) is a start-up focusing on the development and manufacturing of innovative solar technologies. The company was founded in 2011 and is now comprises 10 employees. The capitalisation of SunOyster Systems in 2012 helped the company in bringing an interdisciplinary team together. It constituted the start of the professional development of the SunOyster technology in 2013.

Carsten Corino, the founder of SunOyster Systems was initially working in a wind turbine manufacturing company when he came across the idea of solar co-generation and decided to create his company around this technology.

3.2.2 RD&I activities

Carsten started by joining the company of an engineer who was already working on the technology. After quite a long time with no major advancements with the previous company, Carsten decided to buy the assets from the initial investor and to start afresh by introducing some new changes into the concept. Carsten took over the company and SunOyster Systems was created.

Carsten's personal financial contributions and external investor funds in 2012 allowed to start a more intensive development of the technology. During the following 7 years, SunOyster Systems also managed to attract other private equity investments. Currently, most of the activities of the company are centred on RD&I in order to constantly develop and fine-tune the current complex technology.

The company currently has a Technology Readiness Level of 7 and is striving to receive the TUV Rheinland certification, which would allow them to get the Technology Readiness Level 8. SunOyster Systems wants to reach serial maturity of the technology soon and to become a leading machine builder in the field of solar energy.

3.2.3 Public support

SunOyster benefitted from the support of three following public programmes which have proved instrumental in the uptake of the company's RD&I activities.

- Deutsche Bundesstiftung Umwelt, DBU: The German foundation for the environment is dedicated to the promotion of sustainable technologies. The Foundation enabled the development of the core technology, the hybrid receiver, by providing a grant of 50% the cost.
- SME Instrument Phase II: The programme aims to finance innovation activities such as demonstration, testing, piloting and scaling up, and to provide SMEs with business coaching and acceleration services. The support is in form of a grant of 70% of the cost.
  SunOyster Systems' experience was very positive. The decision-time following the application was much shorter than for the other programmes (it only took 4 months between the time they sent in the application and the moment they received the financial support). In addition, the scope of the programme is very broad and helped to develop also other aspects of the company such as the supply chain, business and public relations.
- Directive for Subsidies for Energy Transition Innovation of the province of Schleswig-Holstein: SunOyster Systems received a grant (48% of cost) from a regional programme (financed by the European Regional Development Fund[4]) and aimed at the development of a new and more advanced version of the technology in place.

3.2.4 Access to finance and Skills as key success factors

[4] European Regional Development Fund, https://ec.europa.eu/regional_policy/en/funding/erdf/, last access on 31.07.19

According to the founder, SunOyster Systems's main success factors are a) the financing programmes they managed to tap in order to develop their core technology and b) the talents they attracted. Indeed, attracting talents in SunOyster Systems's field is getting easier due to the favourable public opinion of green energies.

3.2.5 Access to finance remains a challenge

The main limitation encountered when trying to invest in RD&I were the financial constraints. Indeed, the scientific landscape as well as the information available for RD&I were usually well developed. However, access to finance remained an issue, which was overcome thanks to the public support received as well as the support from external investors as described in the previous sections.

3.2.6 Policy recommendations

Venture Capital investments:
Carsten's view is that it could be really helpful to make venture capital activities more attractive, notably through favourable fiscal policies (i.e. tax incentives) in order to boost investments in SMEs. In addition, while there is a relatively broad spectrum of RD&I programmes in Germany, they are not necessarily open to small SMEs. Indeed, while trying to participate in some programmes, for instance, SunOyster Systems was told that they were still below the threshold of the number of employees.

RD&I grant combined with venture capital loan:
Another recommendation is to combine a RD&I grant with a venture capital loan. However, the decision to allow the loan should be made only at the end of the grant period. This could help SMEs to further develop the activities they initiated thanks to the grant, and further develop them thanks to the venture capital loan, in particular in setting up full scale production in the field of hardware products.

Attractive lending conditions for SMEs:
Finally, while some banks do lend to innovative companies, they often ask for high interest rates and/or guaranteed return levels. Therefore, banks loans are not appropriate for start-ups, which have not yet reached break-even. Therefore, it would be useful to consider possibility of developing programs that could provide more favourable and attractive lending conditions for SMEs, including public guarantees, which limit or eliminate potentially a liability risk for founders.

3.3 Case study 3: Sketch AR

3.3.1 Introduction

SketchAR is a technology company focusing on teaching drawing using augmented reality, machine learning and neural networks. The application is able to put virtual images on paper or a flat surface to let users trace drawings from their mobile phone.

SketchAR is listed amongst the top technology apps by Wired, TechRadar and Tom's Guide, amongst others, listed as one of the most innovative AI-companies in Europe (Deep Knoledge Analitics report), and one of the best AR-companies in education worldwide (Digi-Capital Report). Also, the company was awarded for Best Use of Augmented Reality by Webby Awards.

Andrey Drobitko had previously founded a tech company focused on mobile technology for publishers in 2011. When his first company faced problems, he and his business partners decided to found SketchAR in August 2016. Initially, they spent three years doing research in the field of computer vision and augmented reality. When Snapchat bought a start-up focused on computer vision solutions from Odessa in 2016, he and his business partner knew that it was time to enter the market. His team and his main investor remained the same, which lead to a quicker and easier product development since there was no need for raising funds and finding talent.

3.3.2 RD&I activities

Andrey is the founder and CEO of SketchAR. His team consists of 10 highly skilled PhD and computer vision developers, who focus 80% of their work on research. This is a result of computer vision being extremely new and cutting edge. Initial troubles of finding skilled talent were due to the newness of the computer vision sector. As such, Andrey, who is originally from Russia, sourced his team from Russia which have a legacy in mathematics.

Andrey and his co-founding business partner, spent time "on finding diamonds in the field". They ended up finding a group of PhD students, who were doing research in computer vision, and were able to attract them to start working with them in SketchAR.

The initial idea leading to research activities was the understanding that a normal phone camera cannot work with flat and white surfaces – a blank canvas. Consequently, SketchAR focused its RD&I activities on solving this problem.

With the help of their main investor, a venture capital fund, they were able to raise 150.000 EUR and develop an algorithm that can work fully on flat surfaces, and bring virtual objects to life. The investor was found during an accelerator program in Moscow called Farminers and later with IMI.VC investment fund. This investor introduced the company to the European Regional Development Fund.

3.3.3 Public support

SketchAR benefitted from the support of the two following public programmes which have proved instrumental for the company's RD&I activities.

- Vilnius Tech Park: The Tech Park is an innovation ecosystem for the commercialization of knowledge and technology. SketchAR is able to foster ideas and develop a strong network with visionaries and companies in the computer vision field;
- European Regional Development Fund: The programme aims to finance innovation activities such as supporting the digital agenda, and research SMEs. This Fund helped SketchAR to further develop its white canvas technology, to be able to successfully project virtual reality on a white surface using a phone. (Total funding, Aug 2019 – 750,000 euro from IMI.CV).

3.3.4 Access to Finance, Timing and Ecosystem as key success factors

According to the founder, SketchAR's main success factors lies in the financing they managed to obtain in order to develop their core technology but also in the timing of their operations. Indeed, introducing a product at the right time – not before or after the hype – is essential in securing enough interest and demand. Doing research and watching the

market are key components. Finally, the ecosystem in Lithuania was an essential element to finding the right talent and getting in touch with funds in Europe, and other relevant technology companies focused in the area of computer vision.

3.3.5 Recruiting talent remains a challenge

The main obstacle encountered when trying to grow was attracting the right talent. Given the new and innovative characteristics of computer vision and augmented reality, it is challenging to find developers who are specialised and have experience in the field. However, initiatives such as the Vilnius Tech Park are essential in attracting and meeting highly skilled young minds.

3.3.6 Policy recommendations

Establishment of Tech Parks

Andrey's view is that policies should cooperate with companies to set up and build tech parks in other European countries to match young minds and young people with good companies. This ecosystem would allow SMEs to attract talented individuals and ideas to spread quicker. Policy makers should support in developing infrastructure for SMEs to accelerate their growth in.

Enhanced cooperation for attracting foreign talent:

One obstacle faced by Andrey, was attaining his visa. Closer cooperation between government authorities and technology initiatives would enable companies to recruit foreign talent quicker and more efficiently. Having expedited visa structures would facilitate a more lucrative and attractive talent acquisition process, and ultimately benefit the individual countries in developing a stronger economy.

3.4 Case study 4: Elaphe

3.4.1 Introduction

Elaphe is a high-tech SME active in the development of direct drive propulsion systems for electric vehicles. The company was formally established in 2006. However, the research has been conducted since the 1980's. It offers a complete in-wheel drivetrain solution which is disrupting the mobility market and aims to revolutionize passenger vehicles and spread to other segments in land. It is the world leader in direct-drive solutions and is headquartered in Slovenia.

Gorazd Lampič is the founder and CEO of Elaphe. He is an ambitious entrepreneur with a technical background in physics and alternative energy solutions. Elaphe's CTO, Dr. Gorazd Gotovac, heads the company's development road map. His physics background and specialization in electromagnetics and heat transfer allows for informed and holistic decision-making.

3.4.2 RD&I activities

Elaphe's RD&I team consists of approx. 100 people, of which about 10% have a PhD degree. It is the core of the company. The team mainly focuses on analytical and computer aided engineering (CAE) modelling, mechanical design and vehicle testing.

When the company was founded in 2006, it mainly focused on RD&I for 8 years on research of different types of electric motors. In 2014, the design of the product changed and was introduced to the mass market. In Slovenia, the company has a low volume production line, with ability to produce up to 40 motors per week and investment plans to expand the production capacity in upcoming years. About 40% of Elaphe's employees are working in the production and supporting customer service.

3.4.3 Public support

Elaphe benefitted from the support of the following public programmes which have proved instrumental in the uptake of the company's RD&I activities.

- Horizon 2020: In 2016, Elaphe received SME phase 2 support from Horizon 2020. It helped the company to focus on the industrialisation of L1500 motor for upper-segment electric passenger cars, which has now become one of their most important motors. Additionally, two coaches from European industry were provided to Elaphe, which have helped the company to further promote and develop itself. Elaphe is also very active as a partner in H2020 projects. It has been participating in eleven H2020/FP7 projects since 2012
- Young Researchers Programme for the companies: In the period 2009 - 2013, Elaphe received financing from the Young Researchers Programme initiative for five of their PhD students. This national initiative financially supported individual PhD students during their studies while they were working at Elaphe;
- Incentives to start innovative businesses (P2): Elaphe participated in the P2 program for start-ups which are developing new products. The company received in total 60.000 EUR over the course of three years. This was beneficial for the company, as it served as starting capital;
- Other national initiatives to increase competitiveness of companies: Since 2016, Elaphe also benefited from other national incentives to support competitiveness of the companies. The national programmes were: Enhancing the competencies and innovation potential of companies by SPIRIT Slovenia[5]; Co-financing market research, international forums and certifications by SPIRIT Slovenia; Process improvements by SPIRIT Slovenia; Establishing or upgrading e-commerce in SME by SPIRIT Slovenia; IPR Voucher by Slovene Entreprise Fund; Co-financing of individual performance of companies at international fairs abroad by SPIRIT Slovenia. Elaphe also participated in one Central Europe Interreg project on renewable energies.

[5] SPIRIT Slovenia is a public agency for entrepreneurship, internationalization, fore¬ign investments and technology. https://www.spiritslovenia.si/en.

3.4.4 Industry relationships and timing as key success factors

Overall, the timing of Elaphe was right. The development of the electric vehicle market needs the products offered by Elaphe, both in a global and European context, and provides the opportunity for the company to introduce a stable automotive change. Additionally, Elaphe was able to build strong industry relationships, e.g. through its participation in Horizon 2020 and being a board member of the European Green Vehicle Initiative (EGVI), the Batteries Europe platform and a member of the European Platform for Smart System Integration (EPoSS). These relationships have given the company a strong network and increased visibility.

3.4.5 Ecosystem remains a challenge

The main limitation encountered when trying to invest in RD&I were the lack of regional developers. While Slovenia has good universities, there is significant need for a stronger technological marketplace, which can employ these talented young minds. Additionally, cooperation with large industry players was challenging at first, since getting in touch with these players and becoming visible required effort and time.

3.4.6 Policy recommendations

Enhance joint understanding between public authorities and industry

Regarding national programmes: Developing a joint and aligned understanding of industry needs, would help to better streamline processes and administration work, leading to a more efficient procedure.

RD&I grant combined with venture capital loan

Another recommendation would be to combine a RD&I grant with a venture capital loan. However, the decision to allow the loan should be made only at the end of the grant period. This could help SMEs to further develop the activities they initiated thanks to the grant, and further elaborate them thanks to the venture capital loan, in particular in setting up a mass production in the field of hardware products.

More emphasis on OEM and SME cooperation

European policy makers should focus on fostering more industry cooperation between original equipment manufacturer (OEMs) and SMEs at a European level. Within the different Member States there are different levels of support mechanisms for local SMEs and OEMs. As such, providing a European wide support network can open up and significantly facilitate the cooperation between SMEs and OEMs on a larger geographical scale.

3.5 Case study 5: KELENN Technology

3.5.1 Introduction

KELENN Technology is an SME manufacturing automatic vision solutions, inkjet printers an supervision software for industrial production centres. The company was created in 2005. The company's main market is the printing industry, where it first started with graphics and transactional printing, e.g. paper prints and then continued to shift to industry printing. In 2014 KELENN Technology decided to branch out into the field of printed electronics.

Didier Rousseau is the CEO of KELENN Technology, and has an engineering background in the aerospace industry. His vision is to have a future where everything will be printed. When he started working, the printed electronics market was predominantly located in Asia. He wants to help bring this market to Europe and relocate the industry, particularly in regard to photovoltaic systems and IoTs.

3.5.2 RD&I activities

KELENN Technology invests approximately 60% if its revenues into RD&I. The company started its RD&I activities when the company was created and started in the field of printed electronics in 2014. Didier started the company by himself, and has now 30 employees, where two thirds of his team is dedicated to RD&I activities. Didier focuses on investing into KELENN Technology's human capital, by providing his employees with opportunities for growth, and ensuring that they have relevant knowledge in their area of interest.

The company faced some constraints due to its intensive RD&I commitment. As more than half of the team were engaged in RD&I activities, the ability to serve customers was limited leading to an overall limited increase of the company's customer base. Once the company started outsourcing some of its manufacturing activities, customer service increased, leading to increased growth.

The three main reasons for innovating are: (1) to provide continuous efficiency improvement and growth, (2) satisfy his clients, and (3) continuous commitment to the company's philosophy.

3.5.3 Public support

KELENN Technology benefitted from the support of the following public programmes which have proved instrumental in the uptake of the company's RD&I activities.

- Horizon 2020 (H2020): Through Horizon 2020 KELENN Technology was able to accelerate its growth. H2020 participated into the funding in the range of 1 000 000 EUR for an Industrial additive manufacturing process of conductive, transparent and flexible electrodes with nano formulations for electronic devices such as OPV, OLED, IoTs and displays.
- Crédit d'impôt recherche (CIR) in France: The Crédit d'impôt recherche is a tax refund scheme. It cannot be applied to research programs supported by H2020 funding. However, a number of other research programs where eligible for the CIR support of about 30% of expenses. KELENN Technology applied to be selected amongst the companies which received such a tax refund. As such, the company was able to save funds in the amount of 190 000 EUR for 2017 and reinvest into their RD&I.

3.5.4 Innovation and patience as key success factors

KELENN Technology believes that focusing on developing innovative product tailored to well defined industries requirements and providing the innovation to their actual customers and in priority to new customers, is amongst one of their key success factors in gaining customers' trust and satisfaction. The trust of the customer can go a long way, as it can help the company expand over a long period of time. For example, when a new product is introduced, the trust and relationship with the customer can prove essential in convincing the customer of the newly developed technology.

Additionally, patience when innovating and conducting RD&I activities is an essential aspect of a successful business operation. Mr Rousseau explains that it often takes more time than originally anticipates. KELENN Technology checks along the RD&I process

whether intermediate products can be brought to the market to bridge the time required for RD&I. As such, these smaller products can generate additional revenues while the larger product is still in the research and development phase.

3.5.5 Access to finance remains a challenge

KELENN Technology has experienced a time before and after Horizon 2020. Before H2020 financial resources were limited and growth was only due to the revenues coming from customers. Additionally, the company's visibility was weak. After benefitting from support by H2020, KELENN Technology was able to accelerate its RD&I and growth, particularly in becoming more visible.

3.5.6 To help first sales / Pre sales of critical innovations as the main policy recommendations

In some innovative large industrial project, which are at TRL8 / TRL9 or not yet field proven, Mr Rousseau finds that private companies sometimes have difficulties to take the risk to purchase such innovative product. He believes that for those projects critical to the community, the European Commission or a public / state owned body should take the risk at first and buy this new product as a customer.

For the supplier, there are many advantages:

- A revenue stream of value for the supplier;
- During the life cycle of the innovative product, the customer will be strongly committed to provide relevant feedbacks to the supplier, leading to an optimization of the service. In this way, the product is more tailored to the respective needs;
- Demonstrates to the private sector the business opportunity in the field;
- Develops also a more intimate relationship between SMEs and the public sector.

There are many advantages at the European level:

- Products can serve the European community first;
- Industries or services are developing first in the EU.

3.6 Case study 6: smaXtec

3.6.1 Introduction

smaXtec is a company, which developed their business out of research and development activities from the very start. Mario Fallast and Stefan Rosenkranz founded smaXtec after working on an idea with a research partner at the local academic business incubator – Science Park Graz. With both of their backgrounds in mechanical engineering and electrical engineering, respectively, linking their skills with needs of the agricultural business was driven by curiosity to find concrete high-tech solutions for dairy cow researchers – as well as farmers.

3.6.2 RD&I activities

Research, development and innovation activities predate the founding of the company, starting in 2007 in the Science Park Graz. With the company established in 2009, smaXtec has a central focus on R&DI activities with their main product – the data collecting and transmitting sensors – representing an innovation in the market, a solution that was non-existent prior to their work. The invention of the sensors came as a response to a concrete problem for farmers. SmaXtec develops, sells and distributes monitoring solutions for agribusinesses. Dairy cows swallow a sensor that collect and transfer data to a cloud data base, which are then analysed to provide farm decision-makers with insights for the health management of their stock and ways to increase productivity.

SmaXtec currently employees 43 people serves over 50 000 customers in over 25 countries. Currently, half of the company's staff is made up by engineers, mainly involved in R&DI activities.

3.6.3 Public support

The main public support schemes that SmaXtec benefitted from were the following:

- Horizon 2020 (the biggest EU Research and Innovation programme): SmaXtec received support for developing and preparing their innovation for reaching the market. The scheme targets highly innovative SMEs with a strong ambition to develop, grow and internationalise, and also include coaching and support services. For SmaXtec, Horizon 2020 was particularly helpful for intensive R&D and market access.
- AWS Pre-seed funding is part of the offering by the Austrian federal promotional bank (Austria Wirtschaftsservice). The scheme provided a grant, covering other expenses in the crucial early stage for SmaXtec, besides from R,D&I activities, as well.
- AWS Seed funding targets high-tech startups, specifically focusing on ICT, Physical Science and Life Sciences sectors. smaXtec received a grant through this scheme.
- FFG (Austrian Research Promotion Agency) Basisprogram (special track for startups) is a programme supporting companies in the development of innovative products, processes or services. smaXtec received financing involving a loan and a grant part.
- FFG Innovationscheck (innovation voucher), provided grant funding.
- Grant from the SFG [Steirische Wirtschaftsförderungsgesellschaft mbH], the regional business promotion agency.

Funding through public schemes amounted to 60-70% of the costs for R&DI activities. In the early stages of the company, the founders closed the financing gap wih their own funds and volunteered their own work and time. While the company currently benefits from the support of 10 private investors, finding public funding for R&DI activities is still important. SmaXtec has dedicated an FTE employee to actively work on subsidies applications, their administration and finding consortium partners and following up on changes in funding scheme requirements.

3.6.4 A start-up ecosystem for founders is a key success factor

Since the beginning of their R&DI activities back in 2007, the local business incubator was the main point of reference for the founders. Today, an ecosystem of support for high-tech start-ups has emerged in the region and networking for young companies is an important way of finding partners and learning about funding opportunities.

Besides this, another success factor for SmaXtec is the company's culture – it has managed to remain highly R&DI oriented, while also focusing on addressing customer needs and adapting their product to different agribusinesses. After addressing the international markets for years, the company actually expanded in the Austrian market only a couple of years ago, after developing an appropriate product which met the needs of smaller farms that are typical for Austria.

3.6.5 Finding experienced talent and communicating the value of intangible assets remain challenges

SmaXtec is well-known as an employer locally, as a result of an employer branding strategy, e.g. targeting graduates of the Graz University of Technology. The company is known for their innovation spirit and collaboration culture. In the future, however, recruiting experienced talented professionals might be a challenge for expanding internationally. With international marketing activities focusing on customers, SmaXtec is not widely known to job seekers.

A further challenge to growth and the continuation of RD&I activities within the company is the recognition and understanding of these activities as value-adding. Austrian financial reporting standards are not adapted to reflect the outcomes of investment and expenditures into R&DI activities. SmaXtec chooses to provide additional financial reporting to their investors following international financial reporting standards, which are instrumental in making R&DI expenses and results more visible.

3.6.6 Policy recommendation

While public support schemes, especially in the early stage, are well developed, they could be better tailored to the needs of R&DI-intensive companies. Currently, funding has narrow requirements; companies have to provide project plans, detailing developments for a 2-3 year time horizon. Committing to such plans, however, is inadequate with the nature of R&DI activities, which may require modifications due to changing technological circumsstances, market conditions etc. It is hard to predict what technical standards will apply on the market by the time the project is funded and in development.

While EU- H2020 SME-Instrument seems more flexible to changes to the funded R&DI projects, national funding allows for less deviation from original plans. There should be the option to provide different project scenarios, when applying for funding. Further, there is a need for better communication of funding scheme changes and awareness of existing opportunities. Understanding the existing funding schemes on the EU level required a lot of effort, having a good network was important in this regard to learn from others' recommendations or experience.

3.7 Case study 7: Vortex Bladeless

3.7.1 Introduction

Vortex Bladeless was founded in 2013 by Raúl Martín, David Yáñez and David Suriol. This was not the first company developed by the founders. Preceded by Deutecno, Vortex Bladeless started as one of its many projects.

The first prototype of an innovative blade-free wind turbine that converts wind energy into electricity received attention and financial backing by the Repsol foundation, which awarded the project with EUR 270 000 from its Entrepreneurs Fund (Fondo de Emprendedores de la Fundación Repsol'), one of seven awarded projects, out of 409 competing in 2012.

This led to the birth of the company specialising in wind energy production - the devices invented by the company take advantage of kinetic energy produced by the vortex shedding effect, a technology supported by families of patents from the founders.

3.7.2 RD&I activities

Vortex Bladeless exclusively exercises RD&I activities at this stage. Currently employing 7 people, the company works with prototypes and pilots due to the break-through innovation nature of its product. Efforts are dedicated towards studying the behaviour of the wind turbine device. One of the methods used is a computer simulation, employing predictive models to determine the device's behaviour in the wind.

This requires the use of the facilities like the Barcelona Supercomputing Centre and the use of a specialised software. Acquiring these expensive services has been only possible with the support of the company's network and with financial support by public institutions and private investors.

3.7.3 Public support

The nature of the product that Vortex Bladeless is developing requires large amount of RD&I investments, as it is linked to the use of cutting-edge technology, high cost of manufacturing of prototype parts and the use of industrial facilities. Receiving its first funding as a project, the support by Repsol included also capacity building and linked the founders to a network of other creators. Additionally, the company has benefitted from the following sources of funding:

- Horizon 2020 (the biggest EU Research and Innovation programme): The initiative is supporting SMEs' innovative ideas. Vortex Bladeless received support in June 2016 through the SME-Instrument action. This funding has been instrumental in increasing RD&I activities, but also in terms of connecting with potential industrial partners.
- The Centre for the Development of Industrial Technology (CDTI) in Spain launched the Neotec Capital "Fund of Funds" in cooperation with the European Investment Fund (EIF). Vortex Bladeless benefited from a preferential loan, provided through Neotec.
- OEPM, the Spanish Office of Patents and Trademarks supported Vortex Bladeless in extending their patents abroad.
- ICEX, the Spanish Exports and Investments Agency financed the company's internalisation efforts. The company travelled to the US to participate in networking activities and meet potential investors. Vortex Bladeless consequently launched a crowdfunding campaign with an American crowdfunding platform, successfully raising USD 70 000 in funds.
- The bladeless wind turbines project was supported by ADE (Castile and Leon Region), which provides grants for R&D projects, often covering up to 40% of project costs.
- Vortex Bladeless was also twice supported by PRACE (Partnership for Advanced Computing in Europe), which facilitated the company's access to the Supercomputing Centre in Barcelona for conducting important computer simulations of the product's behaviour.

3.7.4 Securing investments at the edge of technology

Vortex Bladeless is working on the invention, improvement and development of innovative renewable energy technology. Before reaching the market with a product ready for commercialisation, however, the company is working on product prototypes. Finding investors, public and private, who can support an RD&I-intensive process at a pre-commercial stage is challenging. In addition to a computer simulation to test the behaviour of its bladeless wind turbines, the company needs to conduct real life tests as well, since computer models cannot entirely capture real wind patterns complexity.

The company needs a wind tunnel for the real life testing, but installation is very expensive. Additionally, their turbines needs a specially tailored tunnel, manufactured to fit the shape of the devices.

A further obstacle is the manufacturing of prototypes itself. The companies that create the parts needed usually work with moulds and manufacture large quantities, building parts for just one prototype is costly. To circumvent this hurdle, Vortex Bladeless often uses 3D printing and manual work.

In terms of financing, one of the reasons why the company sought contacts with investors in the US was the higher risk appetite among private investors associated with the American tech sector. Currently, however, all of Vortex Bladeless' private investors are Spanish.

3.7.5 Policy recommendation

Relying only on private investors in R&D stages of product development is not sufficient. Before a company is able to bring a product to the market, public financial support is essential. Other EU MS have better developed financing ecosystem with entities dedicated to start-up financing and to growing young companies. More grant support is needed, better tailored to the needs of high-tech RD&I-intensive companies.

3.8 Case study 8: OCTLIGHT

3.8.1 Introduction

OCTLIGHT was founded in 2014 by Thor E. Ansbæk, Kresten Yvind and by Brian Øland. Established in Denmark, Octlight is based at the DTU Science Park. The company was started by a team of engineers and entrepreneurs with an ambition to develop innovative technology to help medical doctors with the treatment of major healthcare problems.

The company, currently commercialising its first product, developed a swept light source technology that makes it possible to take full 3D OCT images of the eye. Full 3D OCT images of the eye are necessary to build a complete image of the eye in order to assess its condition, to increase the ease and certainty in medical diagnostics and to optimise potential treatments for eyes. Currently comprising 8 employees in total, the company has currently allocated 6 of them to intensive RD&I activities in order to develop the product through iteration with a potential customer who will commercialise the OCT device.

3.8.2 RD&I activities

In 2008, Thor E. Ansbæk, the CEO, started a PhD on VCSEL technology and developed, based on his research, a business plan. From the very beginning, the focus was on eyes diagnostics and the business plan aimed to develop a niche technology for eyes that enables real time volume cross-sectional scanning of tissues.
Prior to the creation of the company, and still at the research stage, the founders received a university Proof of Concept grant from the Technical University of Denmark, through which the research was readied for commercialisation. The founders then participated in the Accelerator Danish Tech Challenge, which led to the founding of the company.

3.8.3 Public Support

Starting from the beginning of the company, Octlight enjoyed support from many different national and European grant programs that enabled them to develop the core technology and first product "Caliper", a more efficient and affordable technology than what is currently proposed on the market. All the support programmes were crucial for the company which relied on them for its development.

- The DTU's Proof of Concept grant: The university funding was provided before the creation of the company. The grant aims to help to the future development and maturation of DTU Technologies;
- The GAP – Vækstforum Sjælland: The regional grant funding was provided before the creation of the company to commercialize the technology from the initial customer validation and prototyping in the PoC project;
- The Alexander Foss Industrifond: As private foundation scholarship, the programme is awarded to support Danish industry and financed the first closed-box prototype;
- The CSO MiniPoC: A grant funding from DTU, EU Regional Fund and Vækstforum Hovedstaden towards business development;
- Venture Capital Syddansk Innovation: As a pre-seed venture capital investor in Denmark, the programme help entrepreneurs in an early stage of their projects. The support is provided in the form of equity and loans;
- Innobooster - Danish Innovation Fund: Grant funding for development and market maturation of new products, services and processes to boost growth;
- EUopSTART - Danish Ministry of Higher Education and Science: Danish grant to fund preparation of applications for in European research and innovation;
- Markedsmodningsfonden - Danish Business Authority: As a Danish R&D government funding, the programme is a grant towards product maturation and testing;
- EU SME Instrument Phase 1 - EASME: The outcome of the programme is to produce a feasibility report, including a more elaborated business plan;
- Eurostars - EUREKA: As a joint programme between EUREKA and the European Commission, the scheme supports rapidly marketable innovative products. The scheme is in a form of a grant for innovation action between SME and research

organization in the member countries. (Together with Bern University of Applied Science and RegionH.)

- Actphast: Accelerating Photonics innovation for SME's: a one Stop-shop-incubator is a unique "one-stop-shop rapid prototyping incubator" for supporting photonics innovation by European companies. It is financed by the EC under the Horizon 2020;
- Scale-up Denmark Accelerace: Supported by European Regional Fund, the program supports with business development, assistance coaching for the companies in the go-to-market;
- GROW – The Danish Trade Council: The scheme is a government export subsidy that supports go-to-market in specific countries with assistance from the local Danish Trade Council;
- Eksportsparring – The Danish Trade Council: The programme, a government export subsidy supports SMEs with assistance for researching new markets.

3.8.4 The support programmes as an important success factor

All of the support programmes from which Octlight benefitted were of critical importance, especially the early stage investments. This support helped the technical founders to get the support for business development and R&D to mature and bring to market the innovation. In addition, in Denmark, programmes such as EUopSTART are developed to help small companies to apply for such support programmes. This has proven to be of great importance for small and medium companies that often lack the resources and competences to apply for R&D funding. Navigating through the various support programmes, especially at an EU level can be highly challenging for SMEs. The EUopSTART programme provides external support to SMEs to help them write the applications for the programmes they are aiming to seek support from..

3.8.5 Access to finance remains one of the main challenges for a company like Octlight

Funding and access to finance is very often a challenge for SMEs. In addition to the fiunding received from the support programmes, the company raised funds from private investors. Octlight used its network to find the right partners but it remains a challenge to attract and find the right partners for a company. Octlight succeeded in finding the right private investors with domain knowledge and the maturation through R&D grant funding was critical to get to this stage. Accelerator programmes, such as the Danish Tech Challenge and ScaleUp Denmark, also helped the company to sharpen its business plan and attract investors.

3.8.6 Policy recommendations

To benefit from government support during the commercialisation phase is of crucial importance for companies and especially for start-ups. Traditionally there was a gap between the university research stage and the full commercialisation of the product(s). In Denmark, however, there exist many programmes that are highly focused on the innovation aspects, bringing new products to the market and less focused on more classical research where one is not necessarily focused on the end-result of getting to a commercial stage.

In addition, the Danish environment for SMEs is highly favourable, with many policies that are helpful for companies. In particular, the grant funding from Danish Innovation Fund and The Market Development Fund for supporting RD&I activities at early stages of the company is of great significance for SMEs.

At the European level, it would be very helpful for small and medium companies to have the possibility to apply for programmes where they could receive help from external business people. Those could review their innovation proposal and help in giving feedback to SMEs that are applying for support for RD&I. External people can coach SMEs to reflect and refocus their efforts. This exists as part of the EU SME Instrument.

Finally, it is of crucial importance, both at the European level and at the national level to make application procedures as efficient and fast as possible. The timely receipt of support

is essential to avoid losing the momentum. This is of critical importance when SMEs are introducing new innovations

3.9 Case study 9: Medicortex

3.9.1 Introduction

Medicortex Finland Oy was founded in June 2014 by Adrian Harel and is located in the Turku Science Park Bio-incubator. The company is dedicated to improving the diagnosis and treatment of acute neurodegenerative conditions and is currently focused on developing a diagnostic tool. Over the long term, Medicortex aims to develop novel multifunctional treatment for traumatic brain injury (TBI), as well as for brain injury due to stroke. This medication could potentially prevent the development of chronic conditions such as Parkinson's disease, Chronic Traumatic Encephalopathy (CTE), or epilepsy.

3.9.2 RD&I activities

Adrian Harel, who acts as the CEO of Medicortex is a neurobiologist and an expert in central nervous systems. When, in 2012, the Obama administration launched an effort to improve medical physicians' preparation for diagnosing veterans by increasing coursework on Post Traumatic Stress Disorder (PTSD) and Traumatic Brain Injury (TBI) , Adrian decided to go further with research with the Turku Science park. The CEO therefore found out about the different possibilities of funding for research and decided to create Medicortex to focus on diagnostics and treatments. Medicortex now has 6 employees, all of them fully dedicated to RD&I activities within the company.
Up to now, Medicortex has completed two clinical trials and a third one is planned for this year. The first one was done in Turku in Finland, the second trial in hospitals of three different Finnish cities (Turku, Pori, Vaasa) and the third one is planned to be undertaken in Israel, in Sweden and in Finland.

3.9.3 Public support

Medicortex received several main support programmes since its foundation in 2014:

- Business Finland: The Finnish Funding Agency for Innovation has awarded Medicortex a grant (covering 50% of the costs). The company then applied for a long-term loan at a low interest rate and with a long maturity, the loan for Development and Piloting.

- EU SME Instrument Phase 1: The programme aims to produce a feasibility report and a more developed business plan. The company also received a grant of 50 000 EUR.

3.9.4 Access to finance as an important obstacle to the growth of Medicortex

The main challenge faced by the company is access to funding. Indeed, Medicortex is currently experiencing difficulties in getting other support programmes. According to the CEO, in Finland, companies that are over 4 years old cannot apply for support programmes and grants if they do not have revenues or have not yet commercialised their products or if they don't have a positive balance. For start-ups active in the biotech or pharma sectors this is hardly feasible as such companies require much longer times to develop products and bring them to the market.

In order to overcome its difficulties to access finance, the company will apply for a neurological disease grant (Discovery of Biomarkers and Biomarker Signatures for Neurological and Neuromuscular Disorders) from the U.S. National Institute of Health (NIH). However, Medicortex, as a non-American company, still needs to go through the final approval process to receive the grant. Medicortex also just received a grant from the US Department of Defence (Broad Agency Announcement for Extramural Medical Research). The company also attracted private investors, mainly from the US, Finland and from Israel.

Another challenge faced by the company is, according to Adrian Harel, the lack of infrastructure for drug development in Finland. Indeed, it is essential for Medicortex to have access to infrastructure to test drugs and to produce small quantities of products. The company is therefore turning towards the United Kingdom, which has currently such infrastructure.

Finally, as a biotech start-up, Medicortex experience some difficulties in attracting scientist and chemical engineers with specific training for medical devices. Talents with such qualifications often prefer to work in academia, where they have long-term job security compared to working in a young company.

3.9.5 Policy recommendations

According to the CEO, the first main recommendation would be to change the Finnish law in order to allow companies active in the bio and life science sectors to have at least 7 years to bring a product to the market and enable them to have access to support programmes until then.

Additionally, still according to Mr. Harel, to guide start-ups from early stages of drug developments in Finland, it is necessary to develop centers for drugs testing and evaluations. Indeed, the drug development process is a complex process with numerous steps and to take over the entire process from the idea to its launch is a difficult task for a young company.

Finally, Adrian Harel mentioned the importance for the EU to invest in life science and high-tech to create favourable environments for start-ups developments and growth in those sectors. He mentioned for instance the importance of developing support programmes that can help companies in their research stages. According to him, another example to support investments in companies that are at the research stage would be to offer also a favourable tax regime and incentivise investors who invest in such companies.

3.10 Case study 10: Cybernetica

3.10.1 Introduction

Cybernetica was founded in 1997, emerging from the applied research unit at the Estonian Institute of Cybernetics. The company creates mission-critical IT systems focusing on cybersecurity and e-government, as well as coastal radio communication solutions for maritime authorities.

3.10.2 R&DI activities

Cybernetica's roots lay in R&DI activities, the latter have been central to the company from its very beginning. Up to 20% of the company's expenditures are R&DI spending. Cybernetica's academic research legacy is still present in the company's culture. Over the years, activities have branched out with current work covering applied research areas in the domains of cyber- and information security and computer science. Mainly, the R&DI activities of the company have been focused on building a secure e-government system for Estonia..

Currently, between 80% and 90% of the company's employees have an engineering background. Around 20 employees are involved full-time in R&DI activities being researchers. Engineers and IT architects are sometimes involved in the R&D activities depending on demand.

3.10.3 Public support

The main public support schemes that Cybernetica benefitted from were the following:

- Horizon 2020 (the biggest EU Research and Innovation programme);
- Research funding by the Estonian Ministry of Education and Research for engaging in new research directions and applied research grants;
- The US Defense Advanced Research Projects Agency (DARPA) grants for applied research in the field of information security and privacy.

Funding schemes, especially European ones, have also served to facilitate linkages between the company and European clusters and networks. By funding research, public support accelerates project development.

3.10.4 Success factors and challenges

All funding streams benefitted Cybernetica and supported the company in becoming a market leader in cryptography and cyber security. Financing from Horizon 2020 has made it possible for the company to bring Sharemind – a secure data processing platform – to the market.

Furthermore, building trusting relationships with clients is of substantial importance for R&D intensive companies. Clients willing to undergo the innovation process together with the company profit from innovative tailor-made solutions, at the same time becoming a reference for the expansion of the company's activities. This has been the case with the Estonian government – Cybernetica has implemented solutions based on R&DI activities.

3.10.5 Finding skilled employees remains a challenge

For an RD&I-intensive company, hiring skilled and motivated employees is a main priority. This has proven a challenge for Cybernetica. The ICT sector is very competitive and the company has experienced difficulties in finding people with the right skills in Estonia. Recruiting from outside the EU is also problematic, as administrative formalities take a long time to bring a senior expert from abroad to the job.

Further, the focus of national and European funding policies and schemes seems to be on public-private partnerships between academic research institutions and companies. It could be hard to find consortium partners, excluding some companies from the opportunity to apply.

3.10.6 Policy recommendations

There should be open discussions and public consultations with the government in relation to tax schemes. Stronger support for more exchange between academia and industry would also be beneficial. This could involve more options for academics to do their PhDs in companies or in cooperation with private business, the communication between private sector and academia needs to be supported and encouraged.

There is also the need for more funding schemes that support national R&DI projects in the long term. Innovation policy should involve instruments that ensure long-term stability for projects and companies as short term funding is not optimal for R&DI activities, which may need to be developed over a longer time horizon.

In general, there is not sufficient supply of schemes for companies investing in R&DI. Applying to the existing schemes is not a big hurdle, however, once grants and other funding is received, the management of documentation could represent a disproportioned administrative burden.

Still remaining are legal and regulatory barriers in the single market. Doing business from Estonia, Cybernetica still experiences difficulties to get access to other European markets. There is a lot of room for harmonisation of rules and laws to facilitate the access of European companies to the markets of all Member States.

Outside of Estonia, the EU needs to catch up in some areas to be competitive compared to the US, when it comes to fostering an environment enabling the development of R&DI in the private sector. European funding for SMEs has been directed towards the early development phases of technologies and towards funding consortiums (industry, academia etc.).

While this situation seems to be improving, this has made it more complicated to find funding outside of these artificial consortiums or to get funding for projects at later stages. There should be support for the entire spectrum of R&DI activities – from early stage to product launch. This means that European funding programs and institutions need to take a lot more risks as there will be companies and products that fail, and it must be acknowledged that failing is okay. Funding should not stop once there is a proof of concept, as at that stage a product is still far from the market. In the US, there is a big push to invest in bringing products from idea to market validation.

4 What explains differences in SME innovation activity at the macroeconomic level

This chapter presents the results of an econometric analysis of the country-level determinants of innovation among SMEs. The empirical analysis sought to relate both historical developments and cross-country variation in SME RD&I prevalence to a number of potentially relevant factors:

- General structural factors that may impact incentives to innovate, such as the ease of getting credit, the level of competition, product market regulation or barriers to entrepreneurship. Further structural factors relating to industry composition such as high-technology exports as a percentage of total exports.

- Cyclical factors such as the short-term and long-term interest rates, the unemployment rate and the output gap in each country.

- Factors reflecting specific innovation environment faced by SMEs, such as the countrywide SME R&D tax subsidy rate or the quality and quantity of RD&I infrastructure and resources. The latter includes, for example, the extent of

The outcome variable of interest is the percentage of SMEs in the country that undertook at least one product or process innovation.

The econometric analysis entails considerable identification difficulties. Nevertheless, three stable and robust relationships are identified:

Controlling for the country's general economic development, a higher share of university graduates in science, manufacturing, engineering, and construction is associated with a greater share of innovative SMEs.

Similarly, countries with higher quality research institutions have a more innovative SME sector.

Counterintuitively, a larger share of high-technology exports in a country is associated with a lower share of innovative SMEs. A possible explanation is that in more high-tech economies, SMEs find it comparatively more difficult or less advantageous to undertake innovation.

The next sections describe the data and the econometric model, before discussing in greater detail the main results and their limitations.

4.1 Data and econometric model

The dependent variable is the share of SMEs that undertook at least one product/process innovation in the SMEs population. The information is taken from three waves of the Community Innovation Survey (CIS) database, representing the following three-year reference periods: 2010-2012, 2012-2014 and 2014-20166. Data prior to this has not been used due to a lack of data coverage of explanatory variables, and due to survey methodology differences prior to 20087.

The explanatory variables that were gathered for the empirical analysis are summarised in Table 1. They include a range of broader structural and cyclical factors, as well as indicators specific to SME innovation.

[6]Explanatory variables are mapped to the second year of each CIS survey reference period. I.e 2015 is mapped to the CIS reference period 2014-16.

[7] The industry coverage of the aggregate CIS measures for CIS 2012 – 2016 differs from CIS2008. Specifically, post-2008 it includes NACE Rev. 2 sectors: B, C, D, E, G46, H, J, K and M71-72-73. In 2008 it only includes NACE Rev. 2 sectors: B, C, D, E, G46, H, J58, J61, J62, J63, K and M71.

Table 1 Explanatory variables: Variable names and definitions

Variable	Description	Source
Structural/Cyclical		
Output gap	Output gap as a percentage of potential GDP	OECD
LT interest rate	Long-term interest rate on government bonds	OECD
ST interest rate	Short-term interest rate	OECD
High-tech exports	High-technology exports as a % of total exports	Eurostat
GDP per capita	GDP in current prices purchasing power standard per capita	Eurostat
Unemployment	Unemployment rate	Eurostat
Gross fixed capital formation	Index based on Ratio of total gross capital formation in current local currency to GDP in current local currency.	Global Innovation Index
Quality of innovation linkages		
Uni-industry collaboration	University-industry collaboration in R&D index	IMD World competitiveness report
Linkages	Innovation linkages index	Global Innovation Index
Collaboration2	University/industry research collaboration index	Global Innovation Index
Cluster development	State of cluster development index (Geographic concentrations of firms, suppliers, producers of related products and services)	Global Innovation Index
Availability of funding		
Loan access	Ease of access to loans, index	IMD World competitiveness report
Venture capital	Venture capital availability index	IMD World competitiveness report
R&D GERD	Gross expenditure on R&D (GERD), index	Global Innovation Index
Credit access	Ease of getting credit index	Global Innovation Index
Innovation infrastructure		
Top 500 universities	Top 500 universities, per million population	OECD
Research institution quality	Quality of scientific research institutions index	IMD World competitiveness report
Science graduates	Index of the share of all tertiary graduates in science, manufacturing, engineering, and construction over all tertiary graduates.	Global Innovation Index
ICT	Information and communication technologies (ICTs) infrastructure index	Global Innovation Index
Tertiary education	Govt. expenditure on education, % of GDP	Eurostat
Education	Govt. expenditure on tertiary education, % of GDP	Eurostat
Regulatory framework		
PMR-1	Product market regulation index: Barriers to entrepreneurship, Administrative burdens on start-ups	OECD
PMR-2	Product market regulation index: Ease of entrepreneurship index	OECD
PMR-3	Product market regulation index: Barriers to entrepreneurship, Complexity of regulatory procedures	OECD
PMR-4	Product market regulation index: Barriers to trade and investment, Explicit barriers	OECD
IP Protection	Intellectual property protection index	IMD World competitiveness report
Regulatory quality	Regulatory quality	Global Innovation Index
Incentives		
SME b-index	SME tax subsidies (b-index)	OECD
Competition	Intensity of local competition index	IMD World competitiveness report

The general form of the econometric model is as follows:

$$SME\ product/process\ \ innovation_{i,t} = f(a * Structural/cyclical\ \ factors_{i,t} + b * quality\ of\ innovation\ linkages_{i,t} + c * quality\ of\ innovation\ infrastucture_{i,t} + d * avalibility\ of\ funding_{i,t} + e * regulatory\ framework_{i,t} + f * RD\&I\ Incetives_{i,t})$$

Given that the data are recorded at country-level and the survey years are only every three years, the number of observations is small (generally 90-100). As a result, all potentially relevant explanatory variables could not be included in the model at the same time. A wide range of diagnoses were undertaken to determine the appropriate subsets of variables that were both of interest and could be explored in a stable model.

Most estimated models used GDP per capita (measured in purchasing parity standard) as a control for an economy's capacity to undertake widespread innovation efforts. After controlling for this general measure of economic wealth, the remaining coefficients can be interpreted as economy-wide factors that could affect the innovation incidence among SMEs.

The selected econometric model was the fractional response model[8], where the dependent variable is specified with a logistic function to account for non-linearities. Non-linearities emerge as a result of the dependent variable being a proportion and therefore being bounded to a unit interval.

4.2 Estimation results

A robust relationship between innovation incidence and its potential determinates was found for a limited number of the variables explored (Table 1).

Table 2 shows the headline results. The coefficients from the logistic regression are not directly interpretable, so the results are instead presented as marginal effects. These can be (approximately) interpreted as follows: a small (e.g. 1%) increase in the determinant is associated with a 0.01*(marginal effect) increase in the participation of SMEs in innovation. Unsurprisingly, GDP per capita is consistently a strong predictor of SME participation in innovation. However, even when general economic prosperity is controlled for, specification (3) in Table 2 found a statistically significant influence of research institutions and science graduates on SME innovation.

These indicators capture important aspects of the innovation infrastructure: the ability of scientific research institutes to act as facilitators of innovation and the development of innovation relevant human capital. A 1% increase in the index that measures the quality of research institutions is associated with a 0.07% increase in the share of SMEs that innovate. A similar increase in the share of university science graduates leads to a smaller, but still statistically significant effect on SME innovation.

Model (3) also found that the share of high-tech exports in country's total exports is negatively associated with SME innovation. This result is unexpected and may seem counterintuitive. A possible explanation is that in countries with a greater share of high-tech industries, the innovation landscape is more competitive, and SMEs find it comparatively more difficult or less advantageous to innovate. However, the finding is not very robust. Model (1), which relies on a greater sample size, still identifies a negative association, but it does not identify it as statistically significant.

Table 2 Average marginal effects of SME innovation determinants

Average marginal effects (dy/dx)	(1)	(2)	(3)
Ln(GDP per capita)	0.251***	0.296***	0.155***
	(0.05)	(0.05)	(0.04)
Ln(High-tech exports)	-0.038		-0.070***
	(0.02)		(0.02)
Tertiary education		0.032	
		(0.04)	
Venture capital		-0.006	
		(0.02)	
Research institution quality			0.074***
			(0.02)
Science graduates			0.003**
			(0.00)
Observations	95	88	63

Dependent variable = % of total SMEs undertaking product/process innovation. Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. Includes 3 time periods: CIS reference years 2014-2016, 2012-2014, 2010-2012. Model 3 includes only CIS reference years 2014-2016, 2012-2014.

Controlling for GDP per capita, the regression specification (2) did not find a robust statistical relationship between SME innovation and venture capital access or government expenditure on tertiary education. This result illustrates the challenges faced in relating

[8] This model is appropriate when the dependent variable is a fraction, i.e. a number between 0 and 1.

innovation to its expected determinates. Robust results were also not found for any other explanatory variables listed in Table 1.

The potential impact of product market regulation indicators such as barriers to entrepreneurship (PMR) were estimated cross-sectionally using OLS estimation. This was done because PMR measures are published only once in 5 years.[9] These models sought to relate product market regulation indicators to the incidence of product/process innovation among SMEs, finding no significant results once GDP per capita had been accounted for.

The only model that identified robust relationships – i.e. specification (3) in Table 2 – was also estimated separately for SMEs in the manufacturing and services sectors. These models sought to identify economy-wide factors that may be particularly relevant when only the manufacturing or services sector is considered in isolation. Table 3 presents the results. Model (1) in Table 3 repeats the results presented in Table 2, where the dependent variable is the share of SMEs undertaking product/process innovation. Models (2) and (3) break down the effect by considering only manufacturing SMEs and services SMEs, respectively.

Table 3 Average marginal effects of SME innovation determinants: Manufacturing and services

Average marginal effects (dy/dx)	(1)	(2)	(3)
	All SMEs	Manufacturing SMEs	Services SMEs
Ln(GDP per capita)	0.155***	0.161***	0.148***
	(0.04)	(0.05)	(0.04)
Ln(High-tech exports)	-0.070***	-0.074***	-0.075***
	(0.02)	(0.02)	(0.02)
Research institution quality	0.074***	0.091***	0.076***
	(0.02)	(0.02)	(0.02)
Science graduates	0.003**	0.004***	0.002*
	(0.00)	(0.00)	(0.00)
Observations	95	58	63

Dependent variable = % of total SMEs undertaking product/process innovation. Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. Includes only CIS reference years 2014-2016, 2012-2014. Services refers to NACE Rev. 2 sectors: G46, H, J, K, M71, M72, and M73. Manufacturing refs to NACE Rev. 2 sector C.

Overall, there are few differences between the estimates for the manufacturing sector and the services sector. Both the significance and direction of the identified effects are consistent. Science graduates and research institution quality have higher coefficients in the case of the manufacturing sector than in the case of the services sector, which could suggest that innovation infrastructure plays more of a role in manufacturing sector product/process innovation. The difference, however, is not statistically distinguishable from zero.

4.3 Limitations

The empirical difficulty to identify robust relationships between SME innovation and its potential determinants has largely been the result of collinearity and limited observations. Firstly, many measures of interest have been omitted from the above model due to collinearity with GDP per capita. For example, the variable measuring university-industry collaboration is highly correlated with GDP per capita and research institution quality (with correlation coefficient of approximately 0.8 and 0.9, respectively). Given the limited number of observations, regression analysis is unable to disentangle the possible effects of these indicators from the effect of GDP per capita, leading to large standard errors and model instability.

[9] The 2013 data were mapped to CIS wave 2014-2016.

The reason why the number of observations is limited is the periodicity of the CIS survey, which is run only every 3 years. Many exploratory variables of interest only go back to 2013, resulting in model (3) in Table 2 being estimated with only two CIS survey waves. This not only limits the number of observations in general but more crucially limits within-country variation, or variation over time, in innovation and its determinates. Such variation would be invaluable in relating the effects of changes in policy and other indicators to changes in process/product innovation over time. The lack of within-country variation prevents the use of robust panel data methods which may have been a reliable method in removing unnecessary noise and unobserved heterogeneity in the dependent and explanatory variables.

Furthermore, the lack of significance of some explanatory factors is unsurprising given the limited availability of explanatory variables and the relative crudeness of those that have been explored. Structural and policy variation may play an important role in determining the innovation efforts of SMEs although many of the covariates only capture very limited aspects of the markets and market context that SMEs operate within.

5 What explains differences in R&DI performance by SMEs? An analysis of the SAFE survey

The present section presents the results of a statistical analysis of the factors explaining differences in RD&I performance of EU-28 SMEs using the micro data from the SAFE survey.

5.1 The SAFE Data

The Survey on the access to finance of enterprises (SAFE) is a pan-European survey which, although focused on the financing of businesses, contains a question that allows to identify innovative firms (European Central Bank, 2018).

In a selected number of waves (see below), respondents are asked whether, in the previous 12 months, they have introduced:

- "... a new or significantly improved product or service to the market";
- "... a new or significantly improved production process or method";
- "... a new organisation of management"
- "... a new way of selling [their] goods or services"

These questions closely overlap with the definitions of product, process, organisational and marketing innovation set out in the Oslo manual (OECD/Eurostat, 2005).

5.1.1 Coverage

The survey covers SMEs and large companies across all EU-28 Member States and a number of other countries. Unless otherwise specified, analysis was restricted to firms that were SMEs and located in the EU in all waves in which they were surveyed.

5.1.2 Reference periods

The question on innovation was only asked in waves 1, 5, 9, 11, 13, 15, 17, 19 (i.e. 'common rounds', which are conducted jointly by the ECB and the European Commission). Reference periods range from October to September, except for wave 1, in which the reference period for the innovation questions ranged from July 2008 to June 2009. Observations are assigned to calendar years based on reference period end date .

Table 4 provides a breakdown of the sample used in the econometric analysis by Member State.

As illustrated in Figure 1, the panel is short and unbalanced. A large majority of firms that featured in the econometric analysis only appeared once in the dataset.

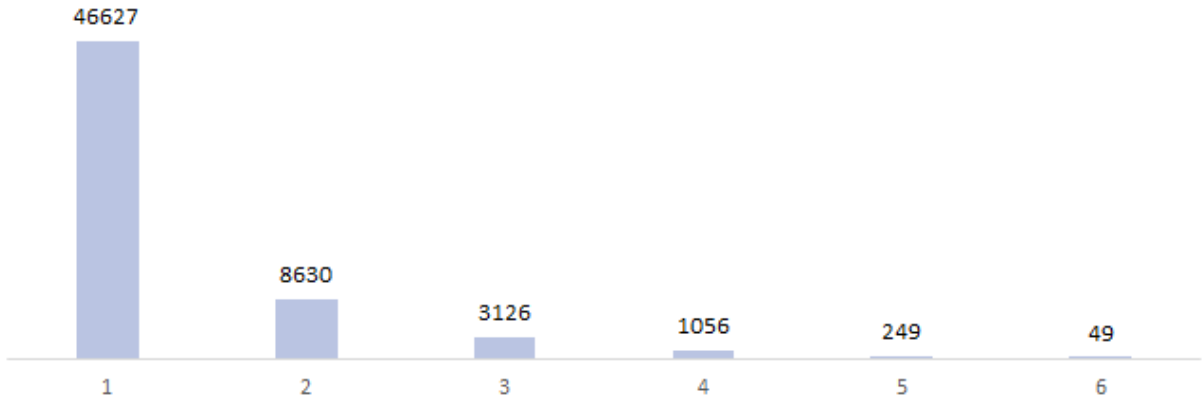
Table 4 Sample size, by country and reference year

	AT	BE	BG	CY	CZ	DE	DK	EE	ES	FI	FR	GR	HR	HU	IE	IT	LT	LU	LV	MT	NL	PL	PT	RO	SE	SI	SK	UK
2009	127	135	137	77	175	253	150	86	251	84	227	181	0	185	66	246	71	82	94	75	152	408	175	166	164	92	89	329
2011	408	433	378	75	412	775	413	85	804	469	847	432	0	421	438	809	234	82	147	73	440	811	422	431	396	83	238	804
2013	428	435	376	81	353	724	390	82	826	452	845	437	79	413	440	816	232	80	144	82	425	784	422	298	370	79	247	747
2014	423	414	397	89	409	1060	398	83	1115	427	1233	455	209	401	420	1319	233	82	152	80	679	899	415	366	389	159	380	893
2015	396	374	317	71	393	1126	380	79	1044	429	1165	322	176	394	391	1280	220	81	154	79	643	955	350	337	342	170	367	991
2016	399	380	411	56	337	1155	355	80	1052	416	1154	361	233	394	409	1255	206	81	128	76	629	907	396	346	348	159	344	1072
2017	427	383	304	63	193	1173	338	88	1057	412	1146	325	208	388	400	1215	211	84	150	52	639	924	420	363	363	149	287	798
2018	415	394	363	75	367	1201	375	85	1103	428	1186	377	215	371	410	1273	233	85	159	71	670	954	400	367	333	162	182	878

Note: Number of observations: 92160. This table is based on firms that featured in the baseline econometric analysis

Source: LE Europe analysis of various waves of the SAFE

Figure 1 Number of enterprises, by number of years in dataset



Note: Number of observations: 59737.this figure reports unique firms that featured in the baseline econometric analysis. Wave 19 is excluded from this figure as firms within that wave could not be linked to previous waves via a static ID.

Source: LE Europe analysis of various waves of the SAFE

Imputations

In order to minimise loss of information, missing values were replaced by their value in the previous wave when that wave had sufficient overlap with the reference period of the innovation variable (e.g. the 'last 6 months' reference period in the waves preceding common rounds ranges from October to March: these months fully overlap with the reference period of the innovation question, which ranges from October to September).

Comparability

In order to provide context for the following results, aggregates from the SAFE were compared to another comprehensive source of country-level innovation information, namely the European Innovation Scoreboard (EIS) 2018 (Hollanders et al., 2018).

As shown in Table 5, there is little overlap between the rankings of countries according to the Summary Innovation Index in the EIS 2018 (first column) and according to the share of innovative SMEs in the last wave of the SAFE, covering 2018 (columns 2,3,6 and 7). This is to be expected, as the Summary Innovation Index is based on a number of other indicators (27 in total) ranging from broadband penetration to R&D expenditure in the public sector. Therefore, SAFE aggregates were also compared to two of the indicators that make up the Summary Innovation Index, namely the shares of SMEs that have undertaken (i) product or process innovations and (ii) marketing or organisational innovations. As the shares of innovators in the EIS 2018 are based on the Community Innovation Survey (CIS) 2014 (covering 2012-2014), these are compared with aggregates from wave 11 of the SAFE, which covers 2014. It can be seen, from a comparison of columns 4 and 5 on one hand, and a comparison of columns 8 and 9 on the other, that both the country-level percentages of innovating SMEs and their relative rankings do not coincide across both data sources.

Therefore, caution should be exercised when drawing conclusions from the descriptive and econometric analysis below.

Table 5 Comparison between SAFE aggregates and EIS 2018

Member States (ranked by EIS 2018 Summary Innovation Index)	Share of SMEs with product or process innovation				Share of SMEs with organisational or marketing innovation			
	SAFE 2018 analysis dataset (unweighted)	SAFE 2018 (weighted)	SAFE 2014 (weighted)	EIS 2018	SAFE 2018 analysis dataset (unweighted)	SAFE 2018 (weighted)	SAFE 2014 (weighted)	EIS 2018
Sweden	38%	38%	45%	40%	31%	32%	47%	35%
Denmark	40%	38%	39%	35%	44%	44%	45%	40%
Finland	65%	63%	55%	44%	53%	54%	55%	37%
Netherlands	32%	31%	41%	43%	34%	33%	47%	33%
United Kingdom	35%	33%	39%	33%	31%	31%	37%	45%
Luxembourg	29%	30%	39%	37%	47%	47%	42%	54%
Germany	33%	32%	38%	42%	35%	34%	36%	49%
Belgium	30%	27%	40%	48%	41%	40%	42%	45%
Ireland	34%	34%	45%	46%	37%	36%	50%	53%
Austria	38%	37%	46%	41%	36%	36%	39%	46%
France	37%	36%	33%	35%	41%	41%	40%	42%
EU-28	39%	34%	42%	31%	38%	34%	39%	35%
Slovenia	59%	55%	55%	33%	40%	38%	44%	33%
Czechia	47%	44%	54%	31%	31%	31%	37%	26%
Portugal	46%	44%	44%	42%	47%	46%	43%	38%
Malta	54%	52%	59%	27%	39%	44%	52%	31%
Spain	34%	32%	39%	19%	43%	43%	46%	26%
Estonia	38%	35%	31%	17%	36%	35%	31%	15%
Cyprus	63%	61%	75%	33%	65%	60%	53%	31%
Italy	43%	41%	44%	33%	44%	43%	37%	35%
Lithuania	46%	44%	51%	34%	32%	32%	30%	24%
Hungary	26%	26%	45%	15%	20%	21%	26%	15%
Greece	42%	41%	43%	35%	51%	51%	44%	40%
Slovakia	51%	50%	52%	17%	40%	39%	32%	22%
Latvia	41%	38%	57%	12%	33%	33%	42%	19%
Poland	36%	37%	49%	13%	24%	24%	34%	11%
Croatia	44%	41%	54%	25%	36%	36%	44%	31%
Bulgaria	44%	41%	44%	14%	36%	35%	32%	15%
Romania	51%	51%	55%	5%	49%	49%	51%	9%

Legend

First column / other columns

Innovation leaders according to the EIS 2018 / Very high share of innovating SMEs relative to other Member States

Strong innovators according to the EIS 2018 / High share of innovating SMEs relative to other Member States

Moderate innovators according to the EIS 2018 / Moderate share of innovating SMEs relative to other Member States

Modest innovators according to the EIS 2018 / Modest share of innovating SMEs relative to other Member States

Note: Member States are ranked by the performance of their innovation system according to the EIS 2018. The shares of innovative SMEs in the EIS 2018 is based on the CIS 2014, which does not include micro enterprises. For comparability, these were excluded from the analysis of the 2014 SAFE in this table. Note that in the SAFE 2014 and 2018 (weighted) aggregates, the sample was restricted to firms for which all innovation indicators were available, whereas the analysis dataset is based on the set of observations for which all innovation indicators and firm characteristics were available. Furthermore, the SAFE 2014 and 2018 (weighted) aggregates are based on observations that were SMEs contemporaneously, whereas the analysis dataset is restricted to firms that were SMEs in all periods.

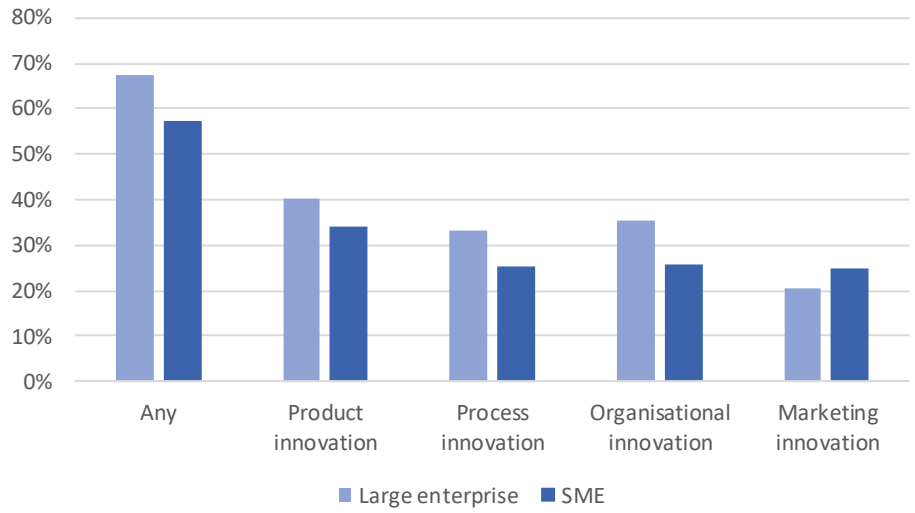
Source: LE Europe analysis of EIS 2018 and SAFE

5.1.3 Key findings of a descriptive statistical analysis

Unless otherwise specified, this section is based on the sub-sample used in the baseline specification in the econometric analysis which includes all observations for which all innovation indicators as well as all firm characteristics were available, and the data are unweighted.

Most surveyed enterprises conducted some innovation. Innovators made up a somewhat larger share of large enterprises than SMEs for most types of innovation, except for marketing innovation (Figure 2).

Figure 2 Share of innovating enterprises, by type of innovation and size

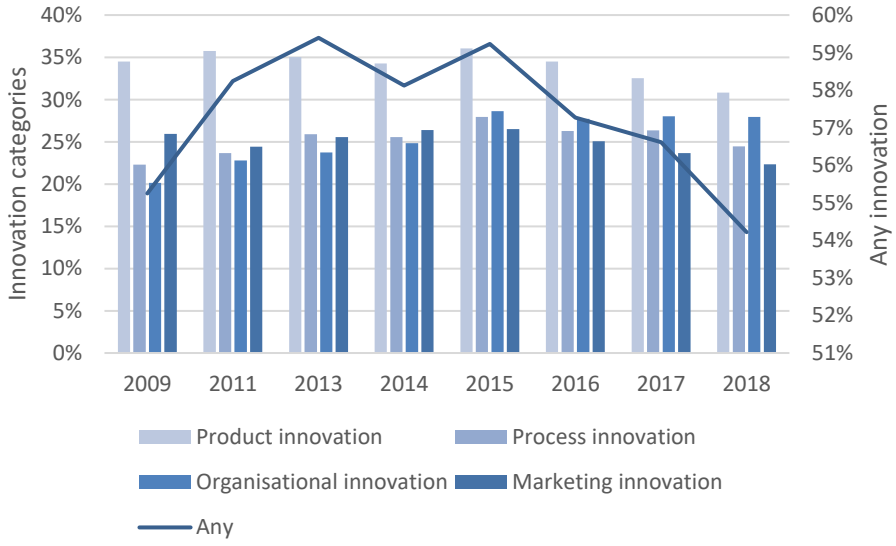


Note: Number of observations: 110316. This analysis draws on all EU-based respondents for which all innovation indicators are available.

Source: LE Europe analysis of various waves of the SAFE

Since 2015, there has been a decline in the share of SME SAFE respondents that have innovated (Figure 3). This has been the case for most types of innovation, except for organisational innovation.

Figure 3 Share of innovating SMEs 2009 to 2018

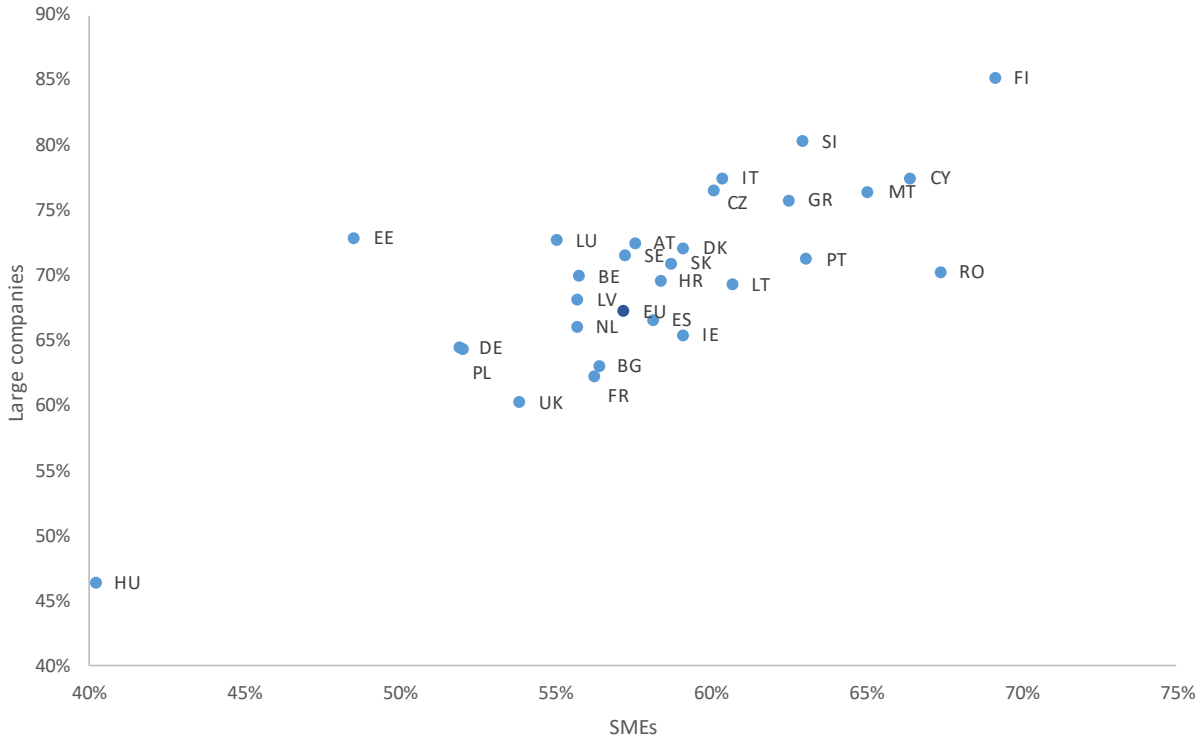


Note: Number of observations: 92160.

Source: LE Europe analysis of the SAFE

Across Member States , the share of innovating SMEs is positively correlated with the share of innovating large enterprises (Figure 4).

Figure 4 Share of innovating enterprises in Member States – large enterprises and SMEs

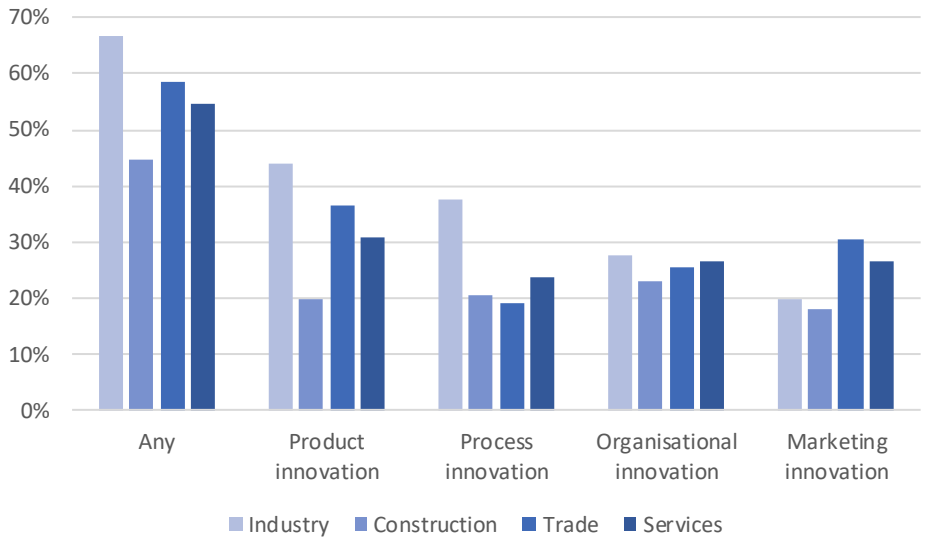


Note: Number of observations: 110316. This analysis draws on all EU-based respondents for which all innovation indicators are available.

Source: LE Europe analysis of the SAFE

Industry has the largest share of innovators. This observation holds for most types of innovation, except for marketing innovation, which is most prevalent in the trade sector (Figure 5).

Figure 5 Share of innovating SMEs by sector

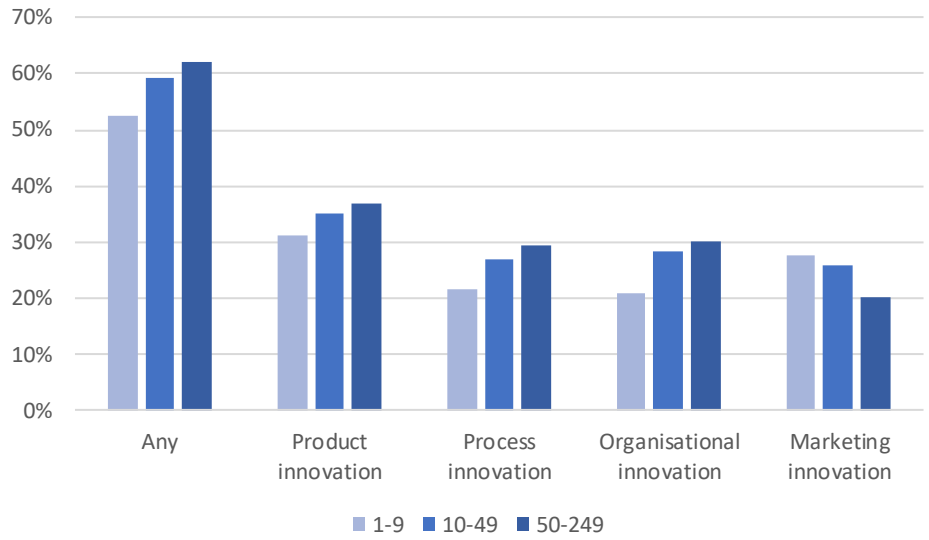


Note: Number of observations: 92160. Sectors correspond to the following NACE Rev. 2 sections: Industry (B, C, D, E), Construction (F), Trade (G), Services (H, I, J, L, M, N, R, S). Sections A, K., O, P, Q, T, U, as well as holding companies are not included.

Source: LE Europe analysis of the EC/ECB Survey on the access to finance of enterprises (SAFE)

For most innovation types, innovators are more prevalent among larger SMEs, although the share of marketing innovations is larger in smaller SMEs (Figure 6).

Figure 6 Share of innovating SMEs by employment size class

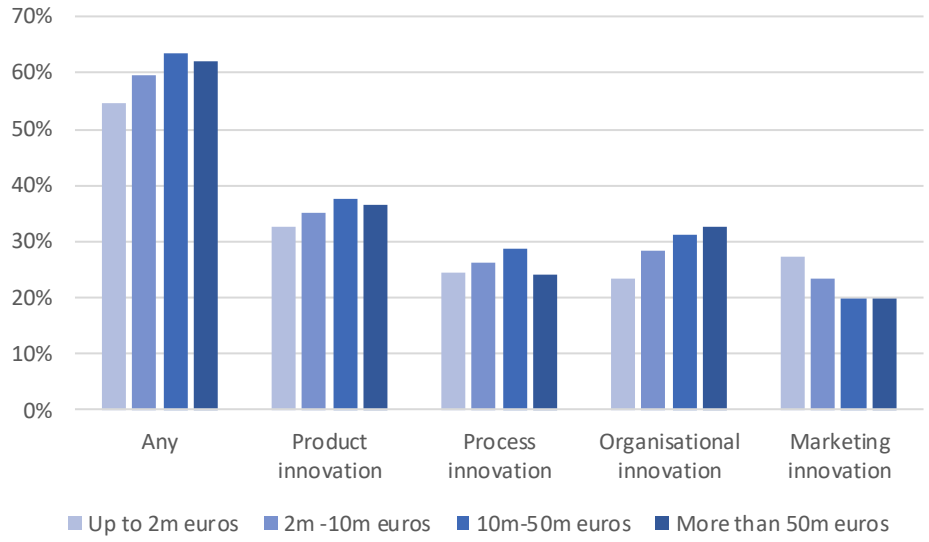


Note: Number of observations: 92160. Size classes are based on the number of employees (full-time or part-time) working for at least 12 hours per week, excluding the owner.

Source: LE Europe analysis of the SAFE

Product and organisational innovators ae more prevalent among SMEs with larger turnover. On the other hand, the share of marketing innovators is lower among SMEs with higher turnover. The shares of process innovators do not markedly differ across turnover ranges (Figure 7).

Figure 7 Share of innovating SMEs by turnover size class

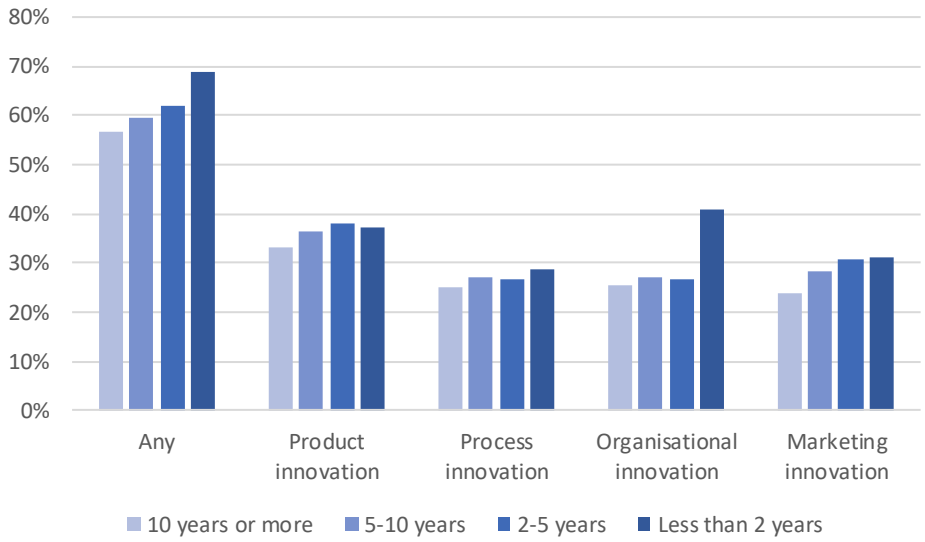


Note: Number of observations: 92160.

Source: LE Europe analysis of the SAFE

Innovators are more prevalent among younger SMEs, although the shares of innovators are fairly similar across age groups in the case of process innovations (Figure 8).

Figure 8 Share of innovating SMEs by age of the SME

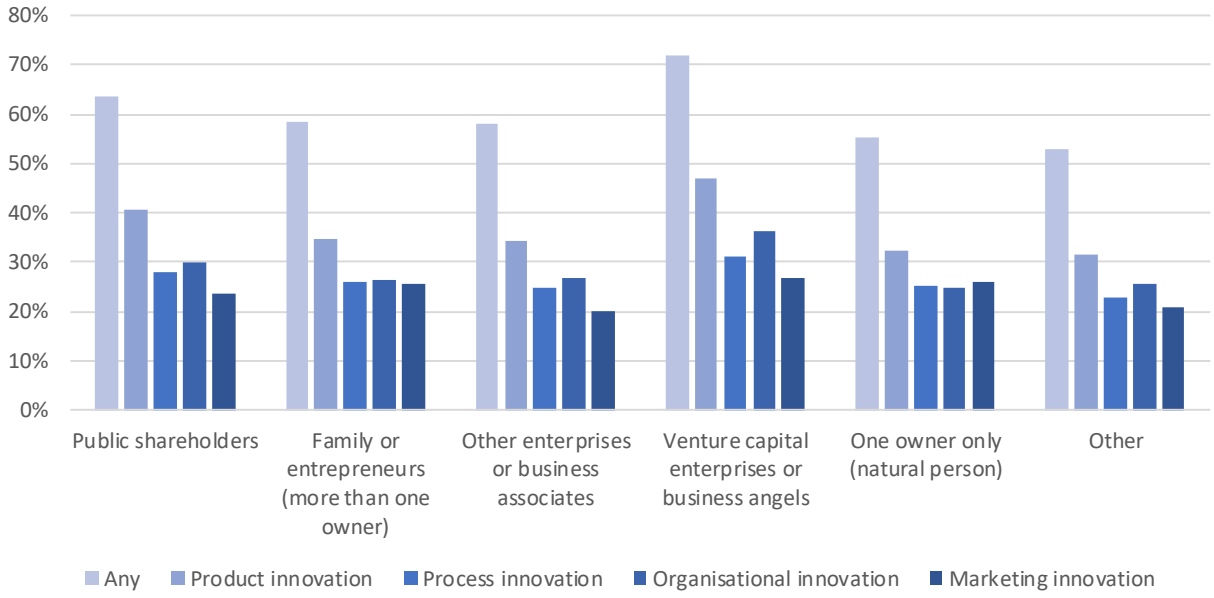


Note: Number of observations: 92160.

Source: LE Europe analysis of the SAFE

The share of innovators is highest among SMEs that are owned by venture capital enterprises or business angels (Figure 9).

Figure 9 Share of innovating SMEs by ownership

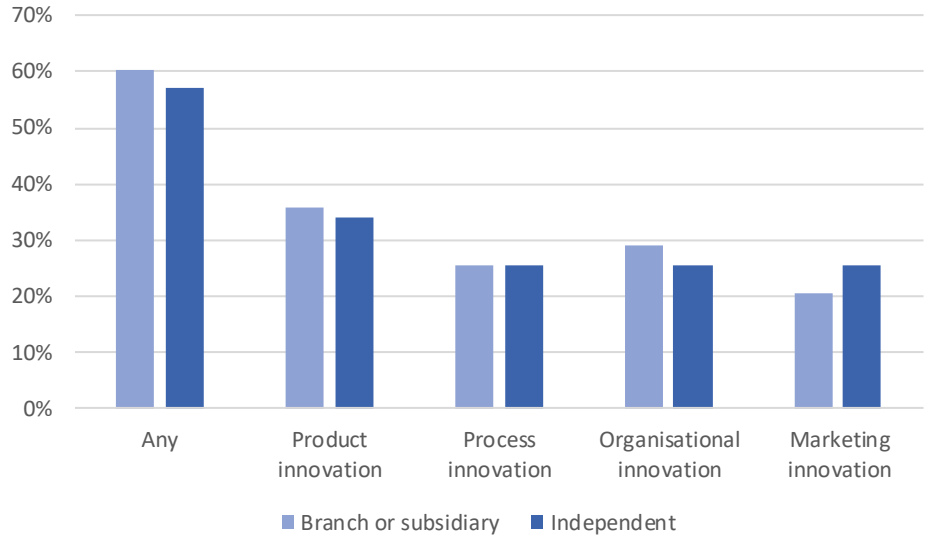


Note: Number of observations: 92160. In the first wave of the SAFE, multiple responses were possible for question D6 on ownership. The microdata contains a recoded version of this variable with a single value for each observation. Therefore, in the first wave, the ownership variable may reflect one of several answers that were given to question D6.

Source: LE Europe analysis of the SAFE

While product and organisational innovators are more prevalent among branches and subsidiaries, there is a higher proportion of process and marketing innovators within independent SMEs (Figure 10).

Figure 10 Share of innovating SMEs by independence status

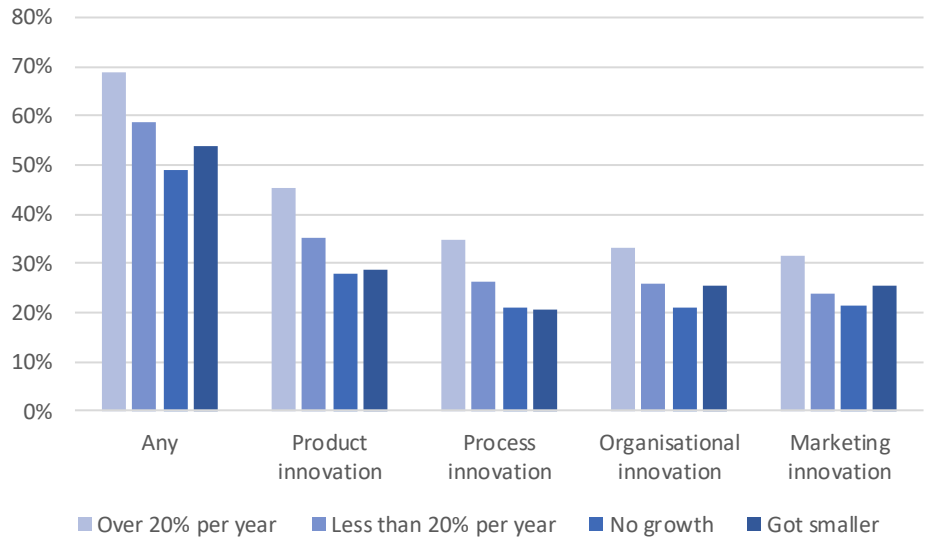


Note: Number of observations: 92160.

Source: LE Europe analysis of the SAFE

Innovators are more prevalent among high-growth SMEs (both in terms of turnover and employment). Interestingly, there is a larger proportion of innovators among SMEs that became smaller than stayed the same size (Figure 11 and Figure 12).

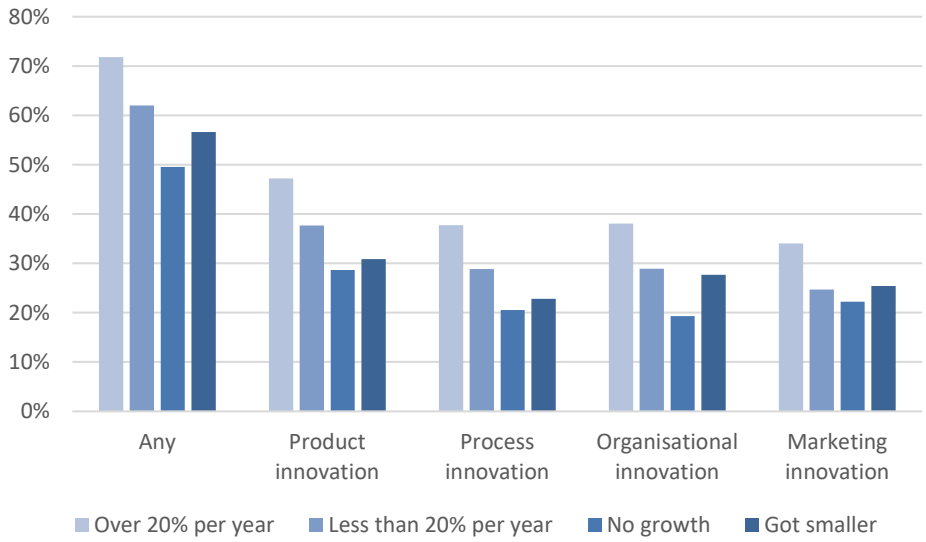
Figure 11 Share of innovating SMEs by turnover growth



Note: Number of observations: 92160. Turnover growth refers to average yearly growth across the past three years (i.e. years t-3, t-2 and t-1)

Source: LE Europe analysis of the SAFE

Figure 12 Share of innovating SMEs by employment growth



Note: Number of observations: 92160. Employment growth refers to average yearly growth across the past three years (i.e. years t-3, t-2 and t-1)

Source: LE Europe analysis of the SAFE

Table 6 shows how different types of innovation are associated. Product innovators are more likely to have undertaken at least one other type of innovation.

It should be noted that cells are not mutually exclusive as a firm may undertake more than two different types of innovations: for instance, an enterprise that has undertaken a product, process and organisational innovation would be included in every cell in the table except for those in the bottom row and far-right column. Elements on the diagonal represent the marginal frequency of innovators for each type of innovation (i.e. the share of innovators, regardless of whether they have also undertaken other innovations).

Table 6 How different types of innovation are associated - % of innovating enterprises

	Product innovation	Process innovation	Organisational innovation	Marketing innovation
Product innovation	34%	17%	12%	14%
Process innovation	17%	26%	11%	11%
Organisational innovation	12%	11%	26%	12%
Marketing innovation	14%	11%	12%	25%

Note: Note: Number of observations: 92160.

Source: LE Europe analysis of the SAFE

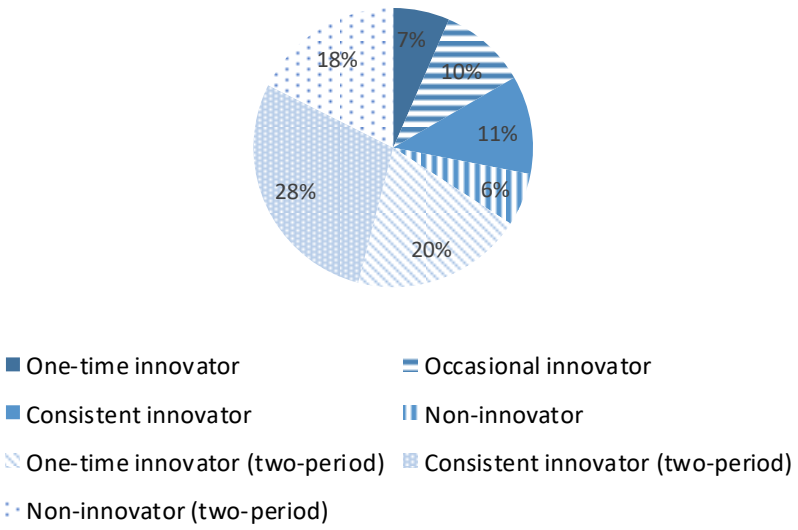
The analysis now draws on the panel structure of the dataset to analyse the innovation pattern of SMEs for which information on innovation behaviour is available for at least two periods. We distinguish between the following types of SMEs:

- **One-time innovators** are SMEs that have been in the dataset for at least three periods and that have innovated in one of these periods;

- **Occasional innovators** are observed in the dataset for at least three periods and have innovated more than once, but not consistently;
- **Consistent innovators** are observed in the dataset for at least three periods and have innovated in every single one of these;
- **Non-innovators** are observed in the dataset for at least three periods and have not innovated in any of these periods;
- **One-time innovators (two-period)** are SMEs that have been in the dataset for two periods and that have innovated in one of these periods;
- **Consistent innovators (two-period)** are observed in the dataset for two periods and have innovated in both periods.
- **Non-innovators (two-period)** are observed in the dataset for two periods and have not innovated in any of these periods.

Consistent innovators make up the largest category among firms that were surveyed only twice (Figure 13). This is also the case among firms that were surveyed at least three times, although the combined share of occasional and 'one-time' innovators makes up a larger proportion of SMEs than consistent innovators.

Figure 13 Innovation pattern of SMEs



Note: Number of observations: 11459 This is based on years 2009-2017. This analysis focuses on unique firms and is based on observations for which information on innovation behaviour is available. For instance, if a firm takes part in four waves of the SAFE, does not have information on innovation behaviour in two of these waves, and has innovated in the other two waves, it will be counted as a Consistent innovator (two-period).
Source: LE Europe analysis of the SAFE

5.2 Key results of the econometric analysis

The following analysis investigates potential determinants of innovation. The dependent variable – whether an SME has undertaken any type of innovation within the past 12 months – is coded as a binary outcome. Models are estimated using logistic regressions.

5.2.1 Innovation and firm characteristics

The first set of models investigates how innovation behaviour is associated with some of the firm characteristics explored above in the descriptive analysis. All variables are categorical and therefore coded as groups of indicators (hence their bolded vector notation). Time dummies are also included in the model in order to control for common

shocks that may be correlated with the covariates. Standard errors are clustered at the country level in order to allow for unexplained factors to be correlated across firms within the same country.

$$\boldsymbol{Probit}(\boldsymbol{innovation}_{it}) = \beta_0 + \boldsymbol{\beta_1 sector}_{it} + \boldsymbol{\beta_2 employment}_{it} + \boldsymbol{\beta_3 turnover}_{it-1} + \boldsymbol{\beta_4 employment\ growth}_{it-1} + \boldsymbol{\beta_5 turnover\ growth}_{it-1} + \boldsymbol{\beta_6 age}_{it} + \boldsymbol{\beta_7 ownership}_{it} + \boldsymbol{\beta_8 independent}_{it} + \boldsymbol{\delta year}_{it} + \varepsilon_{it}$$ [10]

The pseudo-R-squared, indicating goodness-of-fit, is relatively low. However, a Hosmer and Lemeshow test fails to reject the null hypothesis, suggesting that models (1) and (3) fit the data well.

The baseline specification (1) shows that the economic sector in which SMEs operate is associated with innovation as the coefficients (which are reported in exponentiated form, as odds ratios) on all sector indicators are statistically significant (Table 7). Firms in industry (the base category) are most likely to innovate, as illustrated by odds ratios smaller than unity in other sectors.

Small and medium-sized SMEs are more likely to innovate than micro SMEs.

The coefficients on turnover are not statistically significant. Given that turnover and employment capture similar information (the Spearman correlation coefficient between both variables is approximately 0.7), this is not surprising: when the number of employees is removed from the model, turnover gains in significance (not shown). As shown in model (3), coefficients do not change markedly when turnover is removed from the specification.

Younger SMEs are more likely to innovate.

SMEs owned by public shareholders or, unsurprisingly, venture capital enterprises or business angels[11], are more likely to innovate than SMEs that are owned by a family or group of entrepreneurs, which in turn are more likely to innovate than SMEs owned by other enterprises or business associates, or a natural person.

Growing SMEs – especially high-growth businesses – are more likely to innovate than SMEs that have not grown during the past three years, both in terms of employment and turnover. Interestingly, SMEs for which employment or turnover has declined are more likely to innovate.

Innovation does not appear to be associated with SMEs' independence status (i.e. whether it is independent or a branch or subsidiary). This is further investigated later on.

The robustness of this specification is tested by including country dummies in order to account for time invariant country-specific characteristics that may be correlated with both innovation behaviour and the independent variables (e.g. culture, legal framework etc.) – see model (2). The results do not change substantially with the inclusion of Member State indicators and only one coefficient loses significance.

[10] The variable $ownership_{it}$ refers to the type of owner. As specified above, ownership categories include (i) public shareholders, (ii) a family or entrepreneurs, (iii) other enterprises or business associates, (iv) venture capital enterprises or business associates, (v) one owner only. $independent_{it}$ refers to whether the firm is independent, or a branch or subsidiary. The reference year for turnover, as well as the last reference year for turnover and employment growth, are the year prior to the reference period of the innovation variable. Therefore, these covariates are indexed at $t-1$.

[11] This coefficient should be interpreted with caution, as it could reflect both the fact that venture capital may encourage innovation, and the selection of venture capital into innovative firms.

Table 7 Innovation and firm characteristics (logit estimation)

Odds ratios	(1)	(2)	(3)
	Baseline	**Country dummies**	**Without turnover**
Sector			
Construction	0.420***	0.426***	0.419***
	(0.017)	(0.018)	(0.017)
Trade	0.767***	0.773***	0.770***
	(0.030)	(0.035)	(0.031)
Services	0.644***	0.648***	0.640***
	(0.022)	(0.024)	(0.022)
Number of employees			
10-49 employees	1.177***	1.204***	1.188***
	(0.038)	(0.033)	(0.040)
50-249 employees	1.168***	1.228***	1.222***
	(0.059)	(0.047)	(0.052)
Turnover			
2m-10m euros	1.013	1.004	
	(0.039)	(0.027)	
10m-50m euros	1.109	1.088	
	(0.081)	(0.060)	
More than 50m euros	1.040	1.015	
	(0.081)	(0.052)	
Age			
5-10 years	1.110***	1.131***	1.106***
	(0.035)	(0.031)	(0.037)
2-5 years	1.173***	1.201***	1.168***
	(0.030)	(0.029)	(0.032)
Up to 2 years	1.792***	1.855***	1.788***
	(0.185)	(0.177)	(0.184)
Ownership			
Public shareholders	1.104*	1.111**	1.108**
	(0.057)	(0.059)	(0.057)
Other enterprises or business associates	0.894**	0.907***	0.897**
	(0.043)	(0.032)	(0.044)
Venture capital enterprises or business angels	1.488***	1.532***	1.504***
	(0.112)	(0.117)	(0.118)
One owner only (natural person)	0.940*	0.970	0.938*
	(0.031)	(0.024)	(0.031)
Other	0.785***	0.802***	0.784***
	(0.055)	(0.053)	(0.056)
Turnover growth			
Over 20% per year	1.647***	1.676***	1.650***
	(0.060)	(0.057)	(0.059)
Less than 20% per year	1.227***	1.247***	1.229***
	(0.033)	(0.032)	(0.032)
Got smaller	1.097***	1.079**	1.096***
	(0.039)	(0.037)	(0.039)
Employment growth			
Over 20% per year	1.956***	1.911***	1.954***
	(0.066)	(0.066)	(0.066)
Less than 20% per year	1.423***	1.423***	1.426***
	(0.034)	(0.032)	(0.034)
Got smaller	1.317***	1.313***	1.318***
	(0.026)	(0.026)	(0.026)
Independent	0.994	0.976	0.982
	(0.020)	(0.022)	(0.023)
Year dummies	Yes	Yes	Yes
Country dummies	No	Yes	No
Number of observations	92160	92160	92160
Pseudo R-squared	0.036	0.044	0.036
Hosmer and Lemeshow (p-value)	0.668	0.093	0.488

**p<0.1, **p<0.05, ***p<0.01*

Note: Standard errors in parentheses. Baseline categories are: Industry (sector), 1-9 employees, turnover of up to 2m euros, an age of 10 years or more, more than one owner (family or entrepreneurs), no growth (in turnover/the number of employees). Sectors correspond to the following NACE Rev. 2 sections: Industry (B, C, D, E), Construction (F), Trade (G), Services (H, I, J, L, M, N, R, S). Sections A, K., O, P, Q, T, U, as well as holding companies are not included.

Source: LE Europe analysis of the SAFE

5.2.2 Accounting for survey design

The SAFE is not a simple random sample of European SMEs but is based on stratification. Model (5) assesses whether the results obtained above are robust to the use of sampling weights, which account for the over- and under-sampling of certain enterprises based on their sector, country and employment size class within each wave. As illustrated in Table 8, where the baseline specification is also reported for comparison, results are very similar. Minor differences include the loss in statistical significance of the indicator of ownership by public shareholders and single owner. This is not concerning as the point estimates are very close.

Table 8 Sampling weights (logit estimation)

Odds ratios	(4)	(5)
	Baseline	**Weighted**
Sector		
Construction	0.420***	0.430***
	(0.017)	(0.018)
Trade	0.767***	0.748***
	(0.030)	(0.047)
Services	0.644***	0.647***
	(0.022)	(0.028)
Number of employees		
10-49 employees	1.177***	1.157***
	(0.038)	(0.040)
50-249 employees	1.168***	1.171***
	(0.059)	(0.053)
Turnover		
2m-10m euros	1.013	0.983
	(0.039)	(0.031)
10m-50m euros	1.109	1.069
	(0.081)	(0.072)
More than 50m euros	1.040	0.981
	(0.081)	(0.065)
Turnover		
5-10 years	1.110***	1.169***
	(0.035)	(0.039)
2-5 years	1.173***	1.230***
	(0.030)	(0.039)
Up to 2 years	1.792***	1.670***
	(0.185)	(0.191)
Ownership		
Public shareholders	1.104*	1.136
	(0.057)	(0.093)
Other enterprises or business associates	0.894**	0.919*
	(0.043)	(0.044)
Venture capital enterprises or business angels	1.488***	1.462***
	(0.112)	(0.122)
One owner only (natural person)	0.940*	0.937
	(0.031)	(0.040)
Other	0.785***	0.805**
	(0.055)	(0.069)
Turnover growth		
Over 20% per year	1.647***	1.671***
	(0.060)	(0.065)
Less than 20% per year	1.227***	1.219***
	(0.033)	(0.036)
Got smaller	1.097***	1.118***
	(0.039)	(0.047)
Employment growth		
Over 20% per year	1.956***	1.970***
	(0.066)	(0.084)
Less than 20% per year	1.423***	1.433***
	(0.034)	(0.040)
Got smaller	1.317***	1.356***
	(0.026)	(0.037)
Independent	0.994	1.011
	(0.020)	(0.025)
Year dummies	Yes	Yes
Country dummies	No	No
Number of observations	92160	92160
Pseudo R-squared	0.036	0.033

**p<0.1, **p<0.05, ***p<0.01*

Note: Standard errors in parentheses. Baseline categories are: Industry (sector), 1-9 employees, turnover of up to 2m euros, an age of 10 years or more, more than one owner (family or entrepreneurs), no growth (in turnover/the number of employees). Sectors correspond to the following NACE Rev. 2 sections: Industry (B, C, D, E), Construction (F), Trade (G), Services (H, I, J, L, M, N, R, S). Sections A, K., O, P, Q, T, U, as well as holding companies are not included.

Source: LE Europe analysis of the SAFE

5.2.3 Innovation and legal status of firm

In order to test whether the relationship between firm characteristics differs across independent SMEs and branches or subsidiaries, the baseline model was fitted on the two samples of firms and both estimations were compared. For the purpose of testing, the model was fitted through seemingly unrelated estimation in order to account for potential covariance between parameter estimates across both groups of firms. A first test rejects the null hypothesis that coefficients are equal across the two models. Tests on individual coefficients indicate that the following are different across the two samples: the coefficient on employment growth (reduction in employment) is smaller for independent firms, and the coefficients on age (5-10 years and 2-5 years), ownership (Venture capital), and turnover growth (over 20% per year) are larger for independent firms (Table 9).

Table 9 Innovation and firm characteristics – by legal status (logit estimation)

Odds ratios	(6)	(7)
	Independent	**Branches and subsidiaries**
Sector		
Construction	0.416***	0.439***
	(0.019)	(0.031)
Trade	0.757***	0.844**
	(0.031)	(0.073)
Services	0.642***	0.647***
	(0.026)	(0.042)
Number of employees		
10-49 employees	1.176***	1.197***
	(0.039)	(0.077)
50-249 employees	1.184***	1.123
	(0.067)	(0.081)
Turnover		
2m-10m euros	1.007	1.068
	(0.041)	(0.066)
10m-50m euros	1.082	1.213**
	(0.092)	(0.105)
More than 50m euros	1.021	1.102
	(0.098)	(0.106)
Age		
5-10 years	1.126***	0.994
	(0.041)	(0.051)
2-5 years	1.208***	0.949
	(0.030)	(0.094)
Up to 2 years	1.783***	1.870**
	(0.193)	(0.555)
Ownership		
Public shareholders	1.057	1.179**
	(0.062)	(0.083)
Other enterprises or business associates	0.888*	0.895*
	(0.055)	(0.058)
Venture capital enterprises or business angels	1.732***	1.144
	(0.129)	(0.158)
One owner only (natural person)	0.942*	0.905
	(0.031)	(0.066)
Other	0.774***	0.829
	(0.052)	(0.117)
Turnover growth		
Over 20% per year	1.679***	1.420***
	(0.066)	(0.106)
Less than 20% per year	1.230***	1.186**
	(0.035)	(0.081)
Got smaller	1.115***	0.978
	(0.043)	(0.082)
Employment growth		
Over 20% per year	1.964***	1.906***
	(0.073)	(0.145)
Less than 20% per year	1.436***	1.353***
	(0.038)	(0.052)
Got smaller	1.301***	1.405***
	(0.027)	(0.063)
Year dummies	Yes	Yes
Country dummies	No	No
Number of observations	79885	12275
Pseudo R-squared	0.037	0.029
Hosmer and Lemeshow (p-value)	0.137	0.431

**p<0.1, **p<0.05, ***p<0.01*

Note: Standard errors in parentheses. Baseline categories are: Industry (sector), 1-9 employees, turnover of up to 2m euros, an age of 10 years or more, more than one owner (family or entrepreneurs), no growth (in turnover/the number of employees). Sectors correspond to the following NACE Rev. 2 sections: Industry (B, C, D, E), Construction (F), Trade (G), Services (H, I, J, L, M, N, R, S). Sections A, K., O, P, Q, T, U, as well as holding companies are not included.

Source: LE Europe analysis of the SAFE

5.2.4 Innovation and the problems encountered by firms

The next set of models investigates how the innovative behaviour in SMEs may be associated with certain problems encountered by firms. These are:

- Finding customers;
- Competition;
- Access to finance;
- Cost of production or labour;
- Availability of skilled staff or experienced managers;
- Regulation, for example European and national laws, industrial regulations.

Each problem is assigned a score between 1 and 10, where 1 indicates that a given problem is "not at all important" and 10 indicates that it is "extremely important".

The direction of the relationship between problems and innovation can be ambiguous as the latter can influence the former. For instance, non-innovators may have difficulties competing with other firms in their market to attract customers. Likewise, funding and skilled staff are likely to be drawn towards more innovative SMEs. Similarly, process and organisational innovators are likely to find ways to reduce their costs. In order to address this potential simultaneity bias, the problems are lagged relative to innovation behaviour. A drawback of this approach is that sample size is substantially reduced to under 15,000 SMEs because of the unbalanced nature of the panel.

It should also be noted that the mechanism relating the above problems faced by SMEs to innovation behaviour may be twofold. On one hand, the problems may act as barriers to innovation. On the other hand, innovation may be a solution to certain problems. Which of the two effects will prevail is likely to vary across types of innovation. For instance, product innovation may require upfront R&D investments, which may be delayed by limited access to finance. On the other hand, as mentioned above, firms that struggle with costs of production have an additional incentive to enhance the efficiency of their processes and organisation.

Model (8) estimates the relationship between problems faced by SMEs and any type of innovation (i.e. 'generic innovation'). On the other hand, the dependent variables in models (9), (10), (11) and (12) are product, process, organisational and marketing innovation respectively. The following paragraphs discuss how the various problems are associated with each type of innovation. Each problem is modelled as a set of nine indicators, each representing one point on the importance scale described above. The score of 1 ("not important at all") is the base category against which all other coefficients can be compared. The estimation results are reported in Table 10.

Finding customers

Generic innovation is positively associated with assigning importance to the problem of finding customers, as indicated by statistically significant odds ratios greater than 1 on most coefficients (in other words, the odds of an SME innovating are higher if it attaches some importance to the problem of finding customers). This is also the case for product and marketing innovations, which could be interpreted as solutions to the problem (e.g. producing better products or finding better ways to sell them is likely to attract more customers). In contrast, the coefficients on process innovations, which are more closely related to firms' internal functioning, are not statistically significant. Five out of nine of the coefficients on organisational innovation are statistically significant.

Competition

In all models, the majority (if not all) of odds ratios relating to competition are not statistically significant.

Access to Finance

Column (8) suggests that access to finance is positively related to generic innovation, although only the coefficients on higher scores are statistically significant. This suggests that SMEs may innovate in order to attract scarce external funding.

Results vary across different types of innovation. For instance, there is no clear relationship between problems with access to finance and product innovation. This may be because the 'barrier' and the 'solution' effects are of similar magnitude: on one hand, the launch of an improved product can be a compelling incentive for investors. On the other, product development can require large upfront costs and therefore be impeded by barriers to finance.

In the case of organisational innovation, seven of the odds ratios are statistically significant and greater than one. This reflects the intuition that organisational innovations may be used as a solution to the problem of access to finance, as more efficient managerial practices may make more attractive to investors. At the same time, this type of innovation is less likely to require as much upfront investment as product development. Therefore, the barrier effect is unlikely to be at play.

Costs

SMEs that consider production or labour costs are more likely to innovate than companies that do not attach any importance to this problem. Only in the case of marketing innovation are none of the odds ratios significant. The largest odds ratios are estimates in the model of process innovation. This is consistent with the intuition that more efficient processes can reduce costs.

Skills

SMEs which consider the availability of skilled staff or experienced managers to be an important problem are more likely to innovate, both in terms of generic innovation and product innovation.

Regulation

There does not appear to be a clear relationship between regulation and innovative behaviour.

Table 10 Innovation and problems faced by SMEs

Odds ratios	(8)	(9)	(10)	(11)	(12)
Firm characterictics	**Any innovation**	**Product innovation**	**Process innovation**	**Organisational innovation**	**Marketing innovation**
Sector					
Construction	0.349***	0.272***	0.359***	0.839**	0.776**
	(0.037)	(0.025)	(0.032)	(0.068)	(0.090)
Trade	0.706***	0.801***	0.396***	1072	1597***
	(0.047)	(0.066)	(0.033)	(0.059)	(0.146)
Services	0.603***	0.568***	0.495***	1038	1355***
	(0.042)	(0.033)	(0.047)	(0.050)	(0.115)
Number of employees					
10-49 employees	1125**	1022	1202***	1367***	0.914
	(0.054)	(0.079)	(0.078)	(0.089)	(0.062)
50-249 employees	1148*	1037	1259***	1305*	0.826**
	(0.082)	(0.110)	(0.108)	(0.181)	(0.069)
Turnover					
2m-10m euros	0.916	0.874*	0.784***	0.950	0.818**
	(0.071)	(0.060)	(0.069)	(0.064)	(0.064)
10m-50m euros	0.997	0.891	0.813**	1041	0.767**
	(0.102)	(0.074)	(0.072)	(0.117)	(0.085)
More than 50m euros	0.926	0.853	0.643**	1085	0.588**
	(0.149)	(0.118)	(0.113)	(0.165)	(0.126)
Age					
5-10 years	1089	1034	1096	1105	1001
	(0.079)	(0.071)	(0.068)	(0.084)	(0.077)
2-5 years	1118	1125	1070	1225**	1038
	(0.124)	(0.117)	(0.125)	(0.106)	(0.087)
Up to 2 years	2.291***	1301	1383	2.161***	1410*
	(0.473)	(0.311)	(0.357)	(0.591)	(0.290)
Ownership					
Public shareholders	1299*	1406**	1194**	1125	1230
	(0.185)	(0.224)	(0.108)	(0.142)	(0.184)
Other enterprises or business associates	0.913	0.958	0.956	0.894	0.851
	(0.106)	(0.069)	(0.089)	(0.125)	(0.104)
Venture capital enterprises or business angels	1660**	1744**	1163	1775**	1541*
	(0.392)	(0.436)	(0.219)	(0.403)	(0.377)
One owner only (natural person)	0.936	0.926	1005	0.936	0.998
	(0.046)	(0.047)	(0.058)	(0.052)	(0.039)
Other	0.846*	0.991	0.856*	0.875	0.933
	(0.079)	(0.095)	(0.081)	(0.136)	(0.146)
Turnover growth					
Over 20% per year	1573***	1532***	1473***	1366***	1404***
	(0.148)	(0.136)	(0.109)	(0.135)	(0.105)
Less than 20% per year	1304***	1255***	1211***	1151**	1121**
	(0.085)	(0.097)	(0.064)	(0.083)	(0.062)
Got smaller	1061	0.914	0.979	1149	1101
	(0.075)	(0.069)	(0.059)	(0.116)	(0.082)
Employment growth					
Over 20% per year	2.112***	1859***	1898***	2.177***	1640***
	(0.186)	(0.118)	(0.145)	(0.186)	(0.126)
Less than 20% per year	1389***	1405***	1406***	1335***	1225***
	(0.081)	(0.057)	(0.092)	(0.094)	(0.071)
Got smaller	1337***	1216***	1286***	1437***	1114**
	(0.091)	(0.075)	(0.090)	(0.103)	(0.056)
Independent	0.822**	0.903	1064	0.887*	0.995
	(0.068)	(0.060)	(0.073)	(0.062)	(0.075)

**p<0.1 **p<0.05, ***p<0.01*

Odds ratios	(8)	(9)	(10)	(11)	(12)
Problems faced by SMEs	**Any innovation**	**Product innovation**	**Process innovation**	**Organisational innovation**	**Marketing innovation**
Finding customers					
2	1.162	1.020	1.148	1.100	1.263*
	(0.114)	(0.096)	(0.147)	(0.178)	(0.154)
3	1.431***	1.254***	1.081	1.212**	1.126
	(0.124)	(0.107)	(0.096)	(0.105)	(0.132)
4	1.245**	1.217	1.018	0.940	1.343**
	(0.134)	(0.153)	(0.112)	(0.141)	(0.189)
5	1.248***	1.125	0.920	1.288**	1.273***
	(0.075)	(0.094)	(0.059)	(0.129)	(0.118)
6	1.364***	1.298**	0.913	1.373***	1.420***
	(0.126)	(0.169)	(0.096)	(0.149)	(0.163)
7	1.240***	1.125	0.974	1.137	1.347***
	(0.081)	(0.135)	(0.095)	(0.106)	(0.135)
8	1.299***	1.261*	0.860	1.196*	1.388**
	(0.127)	(0.159)	(0.111)	(0.127)	(0.187)
9	1.387***	1.381**	0.863	1.229*	1.373***
	(0.134)	(0.163)	(0.090)	(0.134)	(0.164)
10	1.319***	1.423***	0.847	1.111	1.456**
	(0.124)	(0.182)	(0.093)	(0.102)	(0.219)
Competition					
2	1.362**	1.396***	0.863	1.114	1.417**
	(0.164)	(0.124)	(0.125)	(0.161)	(0.245)
3	1.051	1.096	0.893	0.997	1.139
	(0.136)	(0.115)	(0.101)	(0.130)	(0.164)
4	1.323**	1.262**	0.933	1.066	1.123
	(0.180)	(0.123)	(0.102)	(0.146)	(0.202)
5	1.152	1.173*	0.896	1.013	1.164
	(0.132)	(0.105)	(0.107)	(0.108)	(0.184)
6	1.147	1.079	0.867	1.074	1.312*
	(0.150)	(0.111)	(0.095)	(0.139)	(0.198)
7	1.144	1.062	0.816**	1.041	1.251
	(0.145)	(0.107)	(0.076)	(0.132)	(0.246)
8	1.032	1.017	0.793**	0.909	1.159
	(0.127)	(0.102)	(0.079)	(0.107)	(0.192)
9	1.064	1.024	0.831	1.102	1.108
	(0.145)	(0.119)	(0.101)	(0.119)	(0.217)
10	0.883	0.844	0.810**	0.928	1.117
	(0.097)	(0.100)	(0.076)	(0.110)	(0.184)
Finance					
2	1.033	1.019	0.982	1.022	0.935
	(0.067)	(0.071)	(0.060)	(0.065)	(0.088)
3	1.026	0.880	0.961	1.161**	1.054
	(0.085)	(0.086)	(0.108)	(0.070)	(0.103)
4	1.033	0.905	1.146*	1.006	1.063
	(0.079)	(0.065)	(0.082)	(0.081)	(0.125)
5	1.113	1.067	1.125	1.169**	1.142
	(0.075)	(0.060)	(0.109)	(0.080)	(0.100)
6	1.118	0.846*	0.981	1.379***	1.112
	(0.103)	(0.078)	(0.086)	(0.166)	(0.090)
7	1.171***	1.093	1.024	1.359***	1.133
	(0.071)	(0.100)	(0.077)	(0.096)	(0.123)
8	1.138	0.970	1.109	1.415***	1.286***
	(0.096)	(0.064)	(0.098)	(0.104)	(0.118)
9	1.251**	1.156	0.980	1.613***	1.446***
	(0.122)	(0.134)	(0.078)	(0.170)	(0.158)
10	1.436***	1.152	1.375***	1.888***	1.525***
	(0.153)	(0.100)	(0.145)	(0.180)	(0.179)
Costs					
2	1.402***	1.346***	2.155***	1.374**	1.122
	(0.139)	(0.142)	(0.369)	(0.177)	(0.184)
3	1.148	1.276**	1.984***	1.136	0.971
	(0.127)	(0.125)	(0.421)	(0.166)	(0.147)
4	1.296**	1.417***	1.900***	1.344**	1.182
	(0.156)	(0.155)	(0.376)	(0.164)	(0.160)
5	1.430***	1.429***	2.398***	1.389***	1.076
	(0.118)	(0.112)	(0.418)	(0.138)	(0.134)
6	1.476***	1.470***	2.166***	1.316**	1.112
	(0.152)	(0.149)	(0.459)	(0.157)	(0.158)
7	1.437***	1.332***	2.494***	1.440***	1.079
	(0.163)	(0.134)	(0.481)	(0.192)	(0.140)
8	1.419***	1.249**	2.415***	1.527***	1.083
	(0.164)	(0.128)	(0.498)	(0.171)	(0.152)
9	1.632***	1.314**	2.590***	1.409**	1.271*
	(0.174)	(0.142)	(0.515)	(0.208)	(0.178)
10	1.559***	1.295**	2.627***	1.507***	1.223
	(0.197)	(0.152)	(0.618)	(0.224)	(0.158)
Skills					
2	1.032	1.115	1.033	0.931	0.919
	(0.075)	(0.085)	(0.108)	(0.097)	(0.087)
3	1.309***	1.414***	1.125	1.088	1.096
	(0.090)	(0.133)	(0.083)	(0.086)	(0.092)
4	1.145**	1.087	1.213**	1.086	0.966
	(0.076)	(0.076)	(0.097)	(0.123)	(0.073)
5	1.067	1.145*	1.055	1.016	0.945
	(0.068)	(0.084)	(0.067)	(0.098)	(0.057)
6	1.278***	1.163**	1.122	1.183*	1.112
	(0.090)	(0.079)	(0.093)	(0.111)	(0.107)
7	1.175**	1.229**	1.104	0.982	1.002
	(0.082)	(0.109)	(0.070)	(0.079)	(0.098)
8	1.108	1.189*	1.056	1.062	0.955
	(0.085)	(0.118)	(0.087)	(0.113)	(0.104)
9	1.299***	1.250***	1.132	1.121	0.935
	(0.096)	(0.102)	(0.090)	(0.116)	(0.102)
10	1.333**	1.356**	1.150	1.119	0.927
	(0.169)	(0.196)	(0.111)	(0.100)	(0.127)
Regulation					
2	1.123	1.069	1.030	1.170*	1.026
	(0.080)	(0.105)	(0.089)	(0.101)	(0.107)
3	1.093	1.112	1.034	1.161*	0.869
	(0.077)	(0.113)	(0.095)	(0.101)	(0.089)
4	1.132*	1.057	0.911	1.301***	0.944
	(0.072)	(0.103)	(0.076)	(0.122)	(0.102)
5	1.056	1.020	0.945	1.132*	0.985
	(0.088)	(0.089)	(0.089)	(0.079)	(0.090)
6	0.959	1.016	1.000	1.107	0.847**
	(0.080)	(0.093)	(0.145)	(0.094)	(0.061)
7	1.049	1.074	1.119	1.041	0.925
	(0.075)	(0.087)	(0.171)	(0.080)	(0.082)
8	1.069	1.135	1.074	1.052	0.905
	(0.106)	(0.106)	(0.110)	(0.129)	(0.082)
9	1.094	1.109	1.130	1.121	0.961
	(0.132)	(0.121)	(0.183)	(0.108)	(0.106)
10	1.196**	1.161	1.297**	1.193	1.022
	(0.107)	(0.114)	(0.142)	(0.132)	(0.109)
Year dummies	Yes	Yes	Yes	Yes	Yes
Country dummies	No	No	No	No	No
Number of observations	13700	14653	13828	14721	14722
Pseudo R-squared	0.052	0.049	0.057	0.035	0.035
Hosmer and Lemeshow (p-value)	0.082	0.466	0.508	0.214	0.487

**p<0.1 **p<0.05, ***p<0.01*

Note: Standard errors in parentheses. Baseline categories are: Industry (sector), 1-9 employees, turnover of up to 2m euros, an age of 10 years or more, more than one owner (family or entrepreneurs), no growth (in turnover/the number of employees), and a problem being "not at all important". Sectors correspond to the following NACE Rev. 2 sections: Industry (B, C, D, E), Construction (F), Trade (G), Services (H, I, J, L, M, N, R, S). Sections A, K., O, P, Q, T, U, as well as holding companies are not included.

Source: LE Europe analysis of the SAFE

6 What explains differences in R&DI performance by SMEs? An analysis of the Innobarometer 2016 survey

The present section presents the results of a statistical analysis of the factors explaining differences in RD&I performance of EU-28 SMEs using the micro-data from the Flash Eurobarometer 433 survey (hereafter 'the Innobarometer 2016').

6.1 The Innobarometer 2016 Data

The Innobarometer 2016 covers firms with at least one employee across all EU-28 Member States, as well as two non-Member States. The sample is restricted to firms based in the EU-28 with under 250 employees.

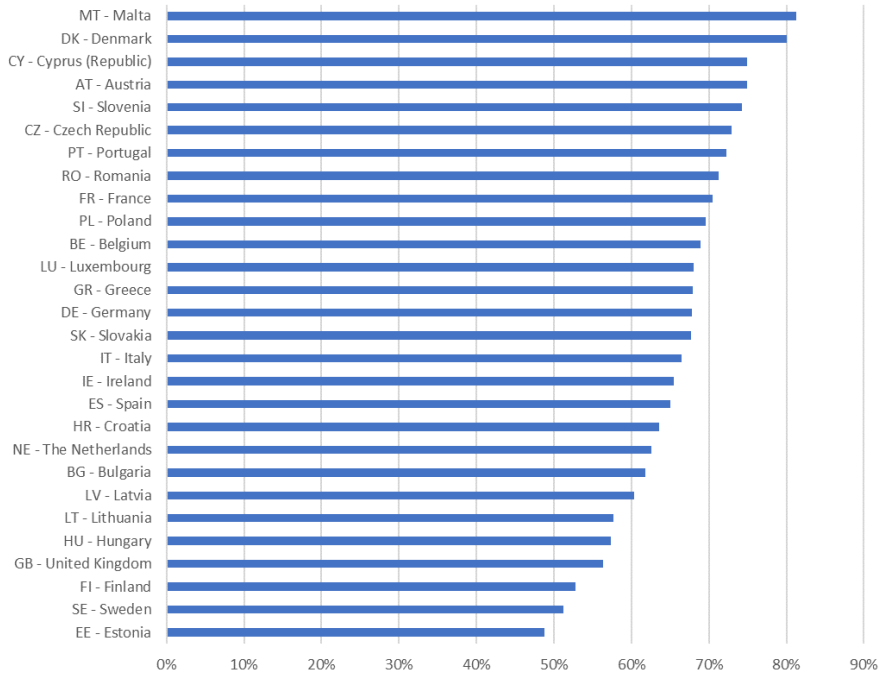
The survey covers the manufacturing, industry and services sectors.[12] Fieldwork was conducted between 1 February and 19 February 2016. Therefore, the reference period of most questions is either early 2016, the year of 2015 (e.g. turnover), or the three years from 2013 to early 2016.

6.1.1 Key findings of the descriptive statistical analysis

Share of innovators, by country

As in the SAFE, the shares of innovators by Member State are not fully consistent with other databases on innovation such as the European Innovation Scoreboard (e.g. the UK, Sweeden and Finland, three of the top scorers in the EIS 2018, have some of the lowest shares of innovating SMEs in the dataset[13]).

Figure 14 Share of innovators, by country



Note: Number of observations: 11865.

Source: LE Europe analysis of the Flash Eurobarometer 433.

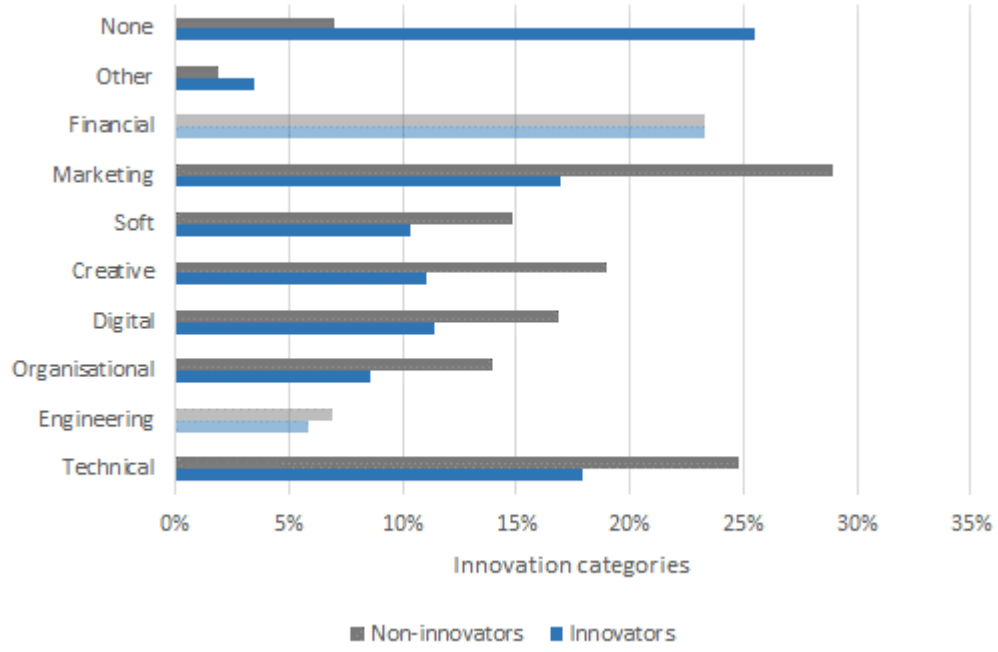
Fostering innnovation – the demand for skills

[12] NACE Rev. 2 sections C, D, E, F, G, H, I, J, K, L, M, N, and R.

[13] It is likely that at least part of these differences is due to the fact that the EIS covers a wider range of indicators than the share of innovators.

Innovators and non-innovators were asked to list two skillsets that could help improve and support innovation activities (innovators), or kick-start them (non-innovators). Figure 15 shows that, for almost every skill, a substantially higher proportion of non-innovators considers that it would be helpful to foster innovation. This result can be explained by two reasons. First, kick-starting innovation activities may be more skills intensive than improving currently existing innovation activities. Second, non-innovators may suffer from sharper skills gaps than innovators *ex ante* (which may at least partially explain the lack of innovation in the first place).

Figure 15 Skills to foster innovation



Note: number of innovators=8321, number of non-innovators=3247. Skills for which there was a statistically significant (95% level) difference between innovators and non-innovators are associated with darker bars.
Source: LE Europe analysis of the Flash Eurobarometer 433.

6.2 Key results of the econometric analysis

6.2.1 Commercialising goods and services and public support measures: a comparison of innovators and non-innovators

In the Innobarometer 2016, respondents were asked to select up to two types of public support which they believe would have the most positive impact on the commercialisation of their goods and services or, in the case of product innovators[14], their *innovative* goods and services. Businesses were also able to list various problems that they may have experienced in the commercialisation of these goods or services.

Drawing on this information, the following paragraphs explore how various problems faced by SMEs are associated with their 'demand' for different types of public support. This analysis is intended to shed light on what SMEs may identify as possible solutions to some of those problems linked to the commercialisation of their products.

[14] Product innovators are firms that have introduced new or significantly improved goods or services since January 2013. In the following paragraphs, the terms 'innovators' and 'product innovators' are used interchangeably. For the purpose of concision, SMEs that have not conducted a product innovation in the past three years are referred to as 'non-innovators' (even though they may have conducted other types of innovation).

To investigate this, separate pairs of logit regressions are estimated for each type of public support measure. Each pair comprises a model for innovators and one for non-innovators,[15] both fitted via seemingly unrelated estimation in order to account for potential correlation in the error terms (i.e. unobserved factors explaining the outcomes) across both equations.

The dependent variable in each model is a binary indicator for each of the following types of public support:

- "Meeting regulations or standards";
- "Accessing or reinforcing online selling";
- "Participating in conferences, trade fairs, exhibitions";
- "Training staff in how to promote and market innovative goods or services";
- "Applying for, managing or protecting intellectual property rights";
- "Market-testing a product or service before launch";
- "Accessing or reinforcing [business's] presence in export markets".

The main independent variables of interest are dummy variables indicating whether the following issues represented a problem with respect to the commercialisation of businesses' (innovative) goods or services:

- "Lack of human resources";
- "Lack of financial resources";
- "Finding or using new technologies";
- "Cost or complexity of meeting regulations or standards";
- "Difficulties in maintaining intellectual property rights";
- "Administrative or legal issues";
- "Lack of marketing expertise";
- "Market dominated by established competitors";
- "Low demand for [business's] goods or services";
- "Weak distribution channels".

In addition, the following firm characteristics are added as control variables, all coded as sets of dummy variables:

- Sector;
- Number of employees;
- Turnover;
- Peariod of establishment;
- Turnover growth;
- Administrative status (whether a business is independent or part of an enterprise group).

Standard errors were clustered at the Member State level. Results are reported as odds ratios.

Meeting regulations or standards

As expected, SMEs are more likely to advocate support in meeting regulations or standards if they experience administrative and legal issues, or are hindered by the cost or complexity of meeting regulations or standards. These results hold for both innovators and non-innovators.

[15] Indeed, given that innovators and non-innovators referred to different types of products in their answers to the survey questions (respectively innovative and non-innovative goods and services), regressions were fit separately on each sample of firms.

Table 11 Public Support: Meeting regulations or standards (logit estimation)

Odds ratios	*Innovators*	*Non-innovators*
	Regulations	
Sector		
Retail (NACE categories G)	0.889	0.735**
	(0.102)	(0.095)
Services (NACE categories H/I/J/K/L/M/N/R)	1.051	0.998
	(0.095)	(0.134)
Industry (NACE categories D/E/F)	1.771***	1.199
	(0.241)	(0.217)
Number of employees		
11 to 49 employees	0.955	0.999
	(0.109)	(0.096)
51 to 249 employees	0.964	0.849
	(0.160)	(0.092)
Turnover		
More than 100 000 to 500 000 euros	1.115	1.214
	(0.134)	(0.163)
More than 500 000 to 2 million euros	1.268	1.207
	(0.214)	(0.155)
More than 2 to 10 million euros	1.096	1.432**
	(0.230)	(0.248)
More than 10 to 50 million euros	1.470*	1.302
	(0.342)	(0.251)
More than 50 million euros	1.504	1.646*
	(0.450)	(0.464)
Age		
Between 1 January 2010 and 1 January 2016	0.933	0.957
	(0.093)	(0.148)
Growth in turnover		
Risen by between 5% and 25%	1.122	0.902
	(0.171)	(0.143)
Remained approximately the same	1.024	1.122
	(0.133)	(0.178)
Fallen by between 5% and 25%	1.244	0.924
	(0.216)	(0.170)
Fallen by more than 25%	1.238	1.214
	(0.301)	(0.288)
Independent	1.072	0.969
	(0.105)	(0.127)
Problems		
Human resources	0.932	0.908
	(0.090)	(0.096)
Financial resources	0.838*	0.891
	(0.077)	(0.087)
New technologies	0.996	1.181
	(0.102)	(0.161)
Regulations and standards	2.779***	3.337***
	(0.241)	(0.449)
Intellectual property rights	1.071	0.900
	(0.124)	(0.089)
Administrative and legal	1.473***	1.501***
	(0.120)	(0.176)
Marketing expertise	0.914	1.063
	(0.060)	(0.116)
Competitors	0.983	0.880
	(0.094)	(0.110)
Low demand	0.724***	0.774**
	(0.049)	(0.085)
Distribution channels	0.801***	0.719***
	(0.065)	(0.087)
Number of observations	5664	3715
Pseudo R-squared	0.0564	0.0718
Hosmer and Lemeshow (p-value)	0.9256	0.1541

**p<0.1, **p<0.05, ***p<0.01*

Note: Standard errors in parentheses. Baseline categories are: manufacturing (sector), 1-10 employees, turnover of up to 100,000 euros, date of establishment before 1 January 2010, growth of over 25%.
Source: LE Europe analysis of the Flash Eurobarometer 433.

Accessing or reinforcing online selling

Here, the profiles of innovators and non-innovators were more contrasted.

Innovators are more likely to advocate support in online selling if they face weak distribution channels. Indeed, e-commerce may help widen their distribution network, which is key to achieve scale. This is particularly important in the case of innovative products that involved high upfront costs (as their profitability often relies on economies of scale).

Product innovators that struggle to find or use new technologies are more likely to advocate support in e-commerce. Indeed, there is a growing market for online selling activities (OECD, 2019). Hence SMEs seeking to kick-start or improve their use of new technologies may see e-commerce as one high potential business activity.

Non-innovators that struggle with low demand or a lack of financial resources are more likley to see value in receiving support in online selling. This may be because e-commerce can help them reach new customers and lower costs (regardless of whether the products sold are innovative): for instance, online selling may reduce the need to invest in physical outlets.

Both innovators and non-innovators lacking marketing expertise are more likely to perceive support in online selling as a high-impact intervention. Indeed, e-commerce typically requires different forms of complementary marketing skills compared to traditional ways of selling. Hence, businesses that have not yet or only recently started to engage in e-commerce may find a need to bridge that skills gap.

Both innovators and non-innovators operating in markets which are dominated by established comppetitors are likely to see value in public support for online selling.

Table 12 Public support: Accessing or reinforcing online selling (logit estimation)

Odds ratios	*Innovators*	*Non-innovators*
	Online selling	
Sector		
Retail (NACE categories G)	1.958***	2.540***
	(0.224)	(0.528)
Services (NACE categories H/I/J/K/L/M/N/R)	1.278***	1.448*
	(0.117)	(0.293)
Industry (NACE categories D/E/F)	0.705***	0.810
	(0.082)	(0.201)
Number of employees		
11 to 49 employees	0.925	0.856
	(0.077)	(0.128)
51 to 249 employees	0.813	0.945
	(0.106)	(0.162)
Turnover		
More than 100 000 to 500 000 euros	1.022	0.914
	(0.096)	(0.124)
More than 500 000 to 2 million euros	0.866	0.907
	(0.080)	(0.161)
More than 2 to 10 million euros	0.824	0.870
	(0.104)	(0.168)
More than 10 to 50 million euros	0.856	0.919
	(0.150)	(0.182)
More than 50 million euros	1.185	1.309
	(0.258)	(0.529)
Age		
Between 1 January 2010 and 1 January 2016	1.058	0.995
	(0.130)	(0.156)
Growth in turnover		
Risen by between 5% and 25%	1.033	1.083
	(0.088)	(0.150)
Remained approximately the same	1.047	0.957
	(0.084)	(0.129)
Fallen by between 5% and 25%	1.220	1.069
	(0.161)	(0.165)
Fallen by more than 25%	1.183	0.666
	(0.200)	(0.180)
Independent	0.844	1.023
	(0.090)	(0.122)
Problems		
Human resources	0.833**	0.784**
	(0.064)	(0.097)
Financial resources	1.035	1.268*
	(0.069)	(0.177)
New technologies	1.197**	1.073
	(0.090)	(0.119)
Regulations and standards	0.970	0.925
	(0.063)	(0.084)
Intellectual property rights	0.891	0.921
	(0.085)	(0.107)
Administrative and legal	0.923	1.031
	(0.079)	(0.113)
Marketing expertise	1.352***	1.654***
	(0.102)	(0.172)
Competitors	1.117*	1.270**
	(0.071)	(0.146)
Low demand	1.077	1.265*
	(0.084)	(0.177)
Distribution channels	1.280***	1.157
	(0.084)	(0.111)
Number of observations	5664	3715
Pseudo R-squared	0.0340	0.0559
Hosmer and Lemeshow (p-value)	0.8405	0.0484

**p<0.1, **p<0.05, ***p<0.01*

Note: Standard errors in parentheses. Baseline categories are: manufacturing (sector), 1-10 employees, turnover of up to 100,000 euros, date of establishment before 1 January 2010, growth of over 25%.

Source: LE Europe analysis of the Flash Eurobarometer 433.

Participating in conferences, trade fairs, exhibitions
Here also, innovators and non-innovators have different profiles.

Product innovators that face weak distribution channels are more likely to advocate public support for participating in conferences, trade fairs and exhibitions. Indeed, these are key networking environments where businesses can promote their innovation and build relationships with potential distributors.

Innovators that lack financial resources are also more likely to advocate support in participating in conferences, trade fairs and exhibitions. Indeed, attending these events can be quite costly to SMEs.

Non-innovators operating in markets that are dominated by established competitors and that face low demand are more likely to expect public support in attending these events to have a strong positive impact on their company.

Both innovators and non-innovators that lack marketing expertise are more likely to advocate public support with respect to participating in conferences, trade fairs and exhibitions.

Table 13 Public support:Participating in conferences, trade fairs, exhibitions (logit estimation)

Odds ratios	*Innovators*	*Non-innovators*
	Trade fairs	
Sector		
Retail (NACE categories G)	0.843*	0.719**
	(0.077)	(0.119)
Services (NACE categories H/I/J/K/L/M/N/R)	0.856**	0.835
	(0.058)	(0.130)
Industry (NACE categories D/E/F)	0.707**	0.520***
	(0.105)	(0.107)
Number of employees		
11 to 49 employees	0.863*	1.019
	(0.066)	(0.127)
51 to 249 employees	0.820*	0.922
	(0.088)	(0.174)
Turnover		
More than 100 000 to 500 000 euros	1.280**	0.959
	(0.151)	(0.131)
More than 500 000 to 2 million euros	1.187	0.858
	(0.150)	(0.145)
More than 2 to 10 million euros	1.384**	0.875
	(0.193)	(0.154)
More than 10 to 50 million euros	1.381*	1.032
	(0.227)	(0.231)
More than 50 million euros	1.235	0.698
	(0.304)	(0.283)
Age		
Between 1 January 2010 and 1 January 2016	1.133	1.258*
	(0.093)	(0.148)
Growth in turnover		
Risen by between 5% and 25%	0.969	1.044
	(0.092)	(0.161)
Remained approximately the same	0.857	0.865
	(0.087)	(0.137)
Fallen by between 5% and 25%	0.626***	0.725*
	(0.082)	(0.125)
Fallen by more than 25%	0.782	0.658
	(0.176)	(0.175)
Independent	1.008	0.688**
	(0.066)	(0.103)
Problems		
Human resources	1.077	1.007
	(0.086)	(0.082)
Financial resources	1.139**	1.047
	(0.072)	(0.085)
New technologies	0.971	0.961
	(0.069)	(0.102)
Regulations and standards	0.813**	0.871
	(0.066)	(0.089)
Intellectual property rights	0.956	0.924
	(0.067)	(0.136)
Administrative and legal	0.960	0.953
	(0.054)	(0.100)
Marketing expertise	1.236***	1.150*
	(0.084)	(0.085)
Competitors	1.055	1.264**
	(0.062)	(0.121)
Low demand	1.027	1.247**
	(0.049)	(0.129)
Distribution channels	1.111*	1.201
	(0.062)	(0.154)
Number of observations	5664	3715
Pseudo R-squared	0.0116	0.0219
Hosmer and Lemeshow (p-value)	0.3727	0.8080

**p<0.1, **p<0.05, ***p<0.01*

Note: Standard errors in parentheses. Baseline categories are: manufacturing (sector), 1-10 employees, turnover of up to 100,000 euros, date of establishment before 1 January 2010, growth of over 25%.

Source: LE Europe analysis of the Flash Eurobarometer 433.

Training staff in how to promote and market innovative goods or services

Barriers associated with 'demand' for training staff in the marketing of innovative products are similar across both innovators and non-innovators.

SMEs that lack human resources and marketing expertise are more likely to advocate support for training staff in promoting innovative goods and services. In both cases, the result is more pronounced among non-innovating SMEs (although the difference between innovators and non-innovators is less marked and non-statistically significant in the case of marketing expertise): non-innovators may have less experience and resources available for promoting innovations than businesses which have already developed product innovations, thereby accentuating any skills gaps.

SMEs that struggle with new technologies are also more likely to favour this type of support. This is not surprising, as marketing and promotion channels increasingly rely on new technologies.

Innovators that operate in markets that are dominated by established competitors are more likely to see value in training staff in how to promote innovative products.

Table 14 Public support: Training staff in how to promote and market innovative goods or services (logit estimation)

Odds ratios	*Innovators*	*Non-innovators*
	Staff	
Sector		
Retail (NACE categories G)	1.793***	1.977***
	(0.195)	(0.294)
Services (NACE categories H/I/J/K/L/M/N/R)	1.978***	2.128***
	(0.171)	(0.259)
Industry (NACE categories D/E/F)	1.634***	1.824***
	(0.196)	(0.320)
Number of employees		
11 to 49 employees	1.517***	1.332**
	(0.133)	(0.158)
51 to 249 employees	1.688***	1.687***
	(0.180)	(0.200)
Turnover		
More than 100 000 to 500 000 euros	0.936	0.937
	(0.121)	(0.102)
More than 500 000 to 2 million euros	1.021	0.917
	(0.154)	(0.099)
More than 2 to 10 million euros	0.871	0.925
	(0.130)	(0.125)
More than 10 to 50 million euros	0.730*	0.795
	(0.122)	(0.139)
More than 50 million euros	0.824	0.881
	(0.188)	(0.214)
Age		
Between 1 January 2010 and 1 January 2016	1.007	0.861
	(0.088)	(0.087)
Growth in turnover		
Risen by between 5% and 25%	1.224**	0.966
	(0.099)	(0.099)
Remained approximately the same	1.300***	0.923
	(0.104)	(0.134)
Fallen by between 5% and 25%	1.026	0.930
	(0.113)	(0.129)
Fallen by more than 25%	0.791	0.614**
	(0.154)	(0.142)
Independent	0.849**	0.935
	(0.059)	(0.097)
Problems		
Human resources	1.228***	1.716***
	(0.091)	(0.171)
Financial resources	0.972	0.994
	(0.065)	(0.101)
New technologies	1.139*	1.291***
	(0.076)	(0.116)
Regulations and standards	0.925	0.845*
	(0.054)	(0.080)
Intellectual property rights	0.723***	0.813
	(0.050)	(0.122)
Administrative and legal	1.089*	1.121
	(0.052)	(0.087)
Marketing expertise	1.434***	1.550***
	(0.110)	(0.150)
Competitors	1.187**	1.103
	(0.086)	(0.081)
Low demand	0.993	0.839*
	(0.083)	(0.080)
Distribution channels	0.851**	1.131
	(0.055)	(0.118)
Number of observations	5664	3715
Pseudo R-squared	0.0300	0.0476
Hosmer and Lemeshow (p-value)	0.2495	0.3703

**p<0.1, **p<0.05, ***p<0.01*

Note: Standard errors in parentheses. Baseline categories are: manufacturing (sector), 1-10 employees, turnover of up to 100,000 euros, date of establishment before 1 January 2010, growth of over 25%.
Source: LE Europe analysis of the Flash Eurobarometer 433.

Applying for, managing or protecting intellectual property rights

Unsurprisingly, SMEs that experience difficulties maintaining intellectual property rights are more likely to advocate support in that respect.

Among SMEs that did not introduce any product innovation since January 2013, those which face administrative and legal issues are more likely to advocate support in applying for, managing or protecting intellectual property rights.

Table 15 Public support: Applying for, managing or protecting intellectual property rights (logit estimation)

Odds ratios	*Innovators*	*Non-innovators*
	Intellectual property rights	
Sector		
Retail (NACE categories G)	0.966	1.142
	(0.212)	(0.418)
Services (NACE categories H/I/J/K/L/M/N/R)	1.061	1.778*
	(0.216)	(0.573)
Industry (NACE categories D/E/F)	0.819	0.962
	(0.203)	(0.435)
Number of employees		
11 to 49 employees	0.704*	1.241
	(0.128)	(0.349)
51 to 249 employees	0.868	1.309
	(0.150)	(0.515)
Turnover		
More than 100 000 to 500 000 euros	1.219	1.060
	(0.217)	(0.248)
More than 500 000 to 2 million euros	0.859	0.680
	(0.140)	(0.163)
More than 2 to 10 million euros	0.652**	0.370***
	(0.132)	(0.113)
More than 10 to 50 million euros	0.805	0.541
	(0.251)	(0.232)
More than 50 million euros	1.235	0.675
	(0.435)	(0.561)
Age		
Between 1 January 2010 and 1 January 2016	0.812	0.850
	(0.144)	(0.281)
Growth in turnover		
Risen by between 5% and 25%	0.834	1.070
	(0.159)	(0.407)
Remained approximately the same	0.936	1.171
	(0.170)	(0.385)
Fallen by between 5% and 25%	0.800	1.064
	(0.197)	(0.478)
Fallen by more than 25%	0.890	1.953*
	(0.258)	(0.726)
Independent	0.861	1.043
	(0.121)	(0.294)
Problems		
Human resources	1.232	0.824
	(0.202)	(0.188)
Financial resources	0.964	0.757
	(0.146)	(0.210)
New technologies	1.222	1.239
	(0.216)	(0.322)
Regulations and standards	0.973	0.833
	(0.121)	(0.152)
Intellectual property rights	5.379***	5.236***
	(0.914)	(1.535)
Administrative and legal	1.156	1.632***
	(0.154)	(0.306)
Marketing expertise	0.740**	0.775
	(0.094)	(0.169)
Competitors	0.829	0.997
	(0.118)	(0.207)
Low demand	0.700**	0.750
	(0.113)	(0.167)
Distribution channels	0.836	0.989
	(0.131)	(0.241)
Number of observations	5664	3715
Pseudo R-squared	0.0920	0.0894
Hosmer and Lemeshow (p-value)	0.9011	0.0068

**p<0.1, **p<0.05, ***p<0.01*

Note: Standard errors in parentheses. Baseline categories are: manufacturing (sector), 1-10 employees, turnover of up to 100,000 euros, date of establishment before 1 January 2010, growth of over 25%.

Source: LE Europe analysis of the Flash Eurobarometer 433.

Market-testing a product or service before launch

Innovators that lack marketing expertise or face low demand are more likely to expect a positive impact from support in market testing. Given that the costs of producing an innovation on a larger scale can be high, especially when added to those of developing the innovation, market testing has the potential to mitigate the risks from launching new products, for which demand may be uncertain ex ante.

Table 16 Public support: Market-testing a product or service before launch (logit estimation)

Odds ratios	*Innovators*	*Non-innovators*
	Market testing	
Sector		
Retail (NACE categories G)	0.853	0.989
	(0.125)	(0.224)
Services (NACE categories H/I/J/K/L/M/N/R)	0.906	0.667*
	(0.097)	(0.161)
Industry (NACE categories D/E/F)	0.687*	0.671
	(0.133)	(0.194)
Number of employees		
11 to 49 employees	0.871	1.201
	(0.111)	(0.262)
51 to 249 employees	0.986	1.587*
	(0.186)	(0.403)
Turnover		
More than 100 000 to 500 000 euros	0.886	1.049
	(0.139)	(0.258)
More than 500 000 to 2 million euros	1.380**	1.006
	(0.224)	(0.223)
More than 2 to 10 million euros	1.305	1.023
	(0.253)	(0.262)
More than 10 to 50 million euros	1.399	0.982
	(0.337)	(0.252)
More than 50 million euros	1.037	0.874
	(0.287)	(0.496)
Age		
Between 1 January 2010 and 1 January 2016	1.082	0.825
	(0.130)	(0.234)
Growth in turnover		
Risen by between 5% and 25%	0.954	0.913
	(0.102)	(0.239)
Remained approximately the same	1.025	0.833
	(0.110)	(0.237)
Fallen by between 5% and 25%	0.880	0.964
	(0.126)	(0.292)
Fallen by more than 25%	0.849	0.693
	(0.155)	(0.255)
Independent	0.885	0.902
	(0.088)	(0.153)
Problems		
Human resources	1.007	0.782
	(0.088)	(0.124)
Financial resources	1.113	1.147
	(0.086)	(0.205)
New technologies	1.072	0.976
	(0.128)	(0.132)
Regulations and standards	0.929	1.109
	(0.069)	(0.177)
Intellectual property rights	1.061	1.108
	(0.133)	(0.249)
Administrative and legal	0.904	1.168
	(0.081)	(0.196)
Marketing expertise	1.153*	1.006
	(0.094)	(0.112)
Competitors	0.959	1.251
	(0.096)	(0.174)
Low demand	1.268**	0.860
	(0.133)	(0.159)
Distribution channels	1.128	1.209
	(0.105)	(0.202)
Number of observations	5664	3715
Pseudo R-squared	0.0130	0.0185
Hosmer and Lemeshow (p-value)	0.4995	0.1709

**p<0.1, **p<0.05, ***p<0.01*

Note: Standard errors in parentheses. Baseline categories are: manufacturing (sector), 1-10 employees, turnover of up to 100,000 euros, date of establishment before 1 January 2010, growth of over 25%.

Source: LE Europe analysis of the Flash Eurobarometer 433.

Accessing or reinforcing your presence in export markets

Both innovators and non-innovators that lack financial resources are more likely to advocate public support in establishing or reinforcing their presence in foreign markets. Indeed, the process of internationalisation can be quite costly.

Innovators that experience difficulties in protecting intellectual property rights are more likely to advocate public support with respect to exporting. Although it is not possible to identify whether these difficulties are specifically linked to businesses' activities in foreign markets, it is conceivable that these SMEs are concerned or uncertain about the status of their intellectual property rights in other countries.

Both innovators and non-innovators facing weak distribution channels are more likely to see high value in receiving support with respect to exporting. Indeed difficulties associated with weak distribution channels may be be exacerbated when conducting cross-border activities.

Non-innovators that lack marketing expertise are more likely to expect public support in exporting to have a highly positive impact on their business.

Both innovators and non-innovators that operate in markets dominated by established competitors are more likely to see value in public support for exporting.

Table 17 Public support: Accessing or reinforcing your presence in export markets (logit estimation)

Odds ratios	*Innovators*	*Non-innovators*
	Export	
Sector		
Retail (NACE categories G)	0.426***	0.422***
	(0.043)	(0.083)
Services (NACE categories H/I/J/K/L/M/N/R)	0.424***	0.386***
	(0.043)	(0.065)
Industry (NACE categories D/E/F)	0.385***	0.265***
	(0.061)	(0.052)
Number of employees		
11 to 49 employees	0.975	0.950
	(0.098)	(0.113)
51 to 249 employees	1.110	1.000
	(0.170)	(0.209)
Turnover		
More than 100 000 to 500 000 euros	1.292**	1.359
	(0.165)	(0.280)
More than 500 000 to 2 million euros	1.715***	2.124***
	(0.225)	(0.422)
More than 2 to 10 million euros	2.025***	2.991***
	(0.333)	(0.541)
More than 10 to 50 million euros	2.346***	3.350***
	(0.433)	(0.798)
More than 50 million euros	2.579***	2.376***
	(0.649)	(0.719)
Age		
Between 1 January 2010 and 1 January 2016	1.218	1.118
	(0.161)	(0.140)
Growth in turnover		
Risen by between 5% and 25%	0.863	0.953
	(0.088)	(0.226)
Remained approximately the same	0.617***	0.778
	(0.060)	(0.189)
Fallen by between 5% and 25%	0.611***	0.717
	(0.068)	(0.172)
Fallen by more than 25%	0.836	1.493*
	(0.142)	(0.335)
Independent	1.389***	1.040
	(0.128)	(0.130)
Problems		
Human resources	1.065	0.991
	(0.101)	(0.099)
Financial resources	1.479***	1.270**
	(0.130)	(0.138)
New technologies	0.992	0.936
	(0.096)	(0.141)
Regulations and standards	0.736***	0.914
	(0.079)	(0.113)
Intellectual property rights	1.223**	0.990
	(0.111)	(0.130)
Administrative and legal	0.923	1.038
	(0.082)	(0.085)
Marketing expertise	0.903	1.286**
	(0.071)	(0.141)
Competitors	1.219**	1.225**
	(0.106)	(0.122)
Low demand	1.135**	1.134
	(0.072)	(0.140)
Distribution channels	1.339***	1.586***
	(0.093)	(0.167)
Number of observations	5664	3715
Pseudo R-squared	0.0531	0.0715
Hosmer and Lemeshow (p-value)	0.7146	0.2664

**p<0.1, **p<0.05, ***p<0.01*

Note: Standard errors in parentheses. Baseline categories are: manufacturing (sector), 1-10 employees, turnover of up to 100,000 euros, date of establishment before 1 January 2010, growth of over 25%.
Source: LE Europe analysis of the Flash Eurobarometer 433.

7 What explains differences in R&DI performance by SMEs? An analysis of the CIS 2014 survey

The present section presents a statistical analysis of the factors explaining differences in RD&I performance of European SMEs using the micro-data from the Community Innovation Survey 2014 (CIS 2014).

7.1 Disclaimer

The analysis below is based on data from Eurostat, the Community Innovation Survey, 2014. The responsibility for all conclusions drawn from the data lies entirely with the authors.

7.2 Introduction

This section explores European SMEs' innovation behaviour through a descriptive and econometric analysis. The descriptive analysis begins by comparing the innovation behaviour of SMEs and large companies within different sectors, before turning to the barriers faced by non-innovators, and finally, an overview of the sample that will be used in the econometric analysis. The econometric analysis explores the relationship between different firm characteristics, and innovation behaviour as well as the incidence of various barriers to innovation.

Some key findings emerge:

- Most results suggest that larger, growing, exporting SMEs which are part of an enterprise group and that operate in the manufacturing, or service sectors are more likely to engage in innovative behaviour, and to do so continuously;
- Barriers related to access to finance are the most prevalent obstacles to innovation among non-innovators[16];
- Among non-innovating SMEs, two phenomena appear to hinder innovation: (i) 'high-intensity' barriers (which tend to be less frequent) and (ii) a combination of multiple 'moderate-intensity' barriers: in some cases SMEs face no high-intensity barrier but a cluster of many moderate-intensity obstacles
- Both the innovation rate and the share of R&D active businesses are much higher among large companies than SMEs in the trade sector (NACE Rev. 2 section G). In contrast, the gap is much lower in the information and communication sector (section J).[17]

7.3 The CIS 2014 Data

7.3.1 Coverage

This analysis is based on the scientific-use files from the CIS 2014. These micro-data files contain information on the innovation behaviour and firm characteristics of 68,476 businesses across thirteen Member States and Norway, including 55,555 EU-based SMEs.[18] The survey covers enterprises with at least 10 employees, so it does not include Micro SMEs. A subset of these businesses were considered for the analysis, based on the following criteria:

- Only SMEs from EU Member States were kept, so Norwegian businesses were excluded from the analysis;

[16] Specifically, non-innovators that considered innovating but did not conduct any innovation activities because the barriers were too high.

[17] These findings are common to both the innovation rate and the share of R&D active businesses but are not the sectors with the highest and lowest differences in each sector. The sectors with the highest and lowest gap in innovation rates between SMEs and large companies are financial and insurance activities (section K) and information and communication technologies (section J), and the sectors with the highest and lowest disparity in the share of R&D active businesses are trade (section G) and administrative and support service activities (section N). See 7.4.1 for more detail.

[18] Here, an SME is defined as a business with 10-249 employees. Note that the 55,555 SMEs do not include Cypriot businesses as no information was available on their employment.

- No information was available on the number of employees in Cypriot businesses, preventing the identification of SMEs. Hence, these were not considered in the analysis;
- Except in 7.4.1, the analysis is restricted to SMEs;
- For each strand of analysis, the sample was further restricted to observations for which relevant variables were available. Numbers of observations are specified below each figure and in regression tables.

7.3.2 Variables

The following paragraphs describe the innovation behaviour indicators and explanatory variables that were used in the descriptive and econometric analyses.[19] Innovation behaviour indicators can be classified into both innovation 'inputs' (e.g. R&D) and 'outputs' (e.g. the introduction of an innovation).

Whether a business has innovated

The main innovation output that is considered is whether a business has introduced one of the following types of innovation in the three years from 2012 to 2014 (Eurostat, 2014):

- The introduction of a "new or significantly improved good or service", or product innovation;
- The "implementation of a new or significantly improved production process, distribution method, or supporting activity", or process innovation;
- A "new organisational method in [an] enterprise's business practices [...] workplace organisation or external relations", or organisational innovation;
- The "implementation of a new marketing concept or strategy", or marketing innovation.

Although these innovations should be novel within the enterprise, they need not be new to the market.

In addition, another proxy for innovation was constructed, indicating whether a business has introduced a product or process innovation.

Both indicators are considered in the descriptive and econometric analyses (as outcome variables).

Applications for intellectual property protection

Another innovation output measure is whether a business has applied for intellectual property protection in the three years between 2012 and 2014. This can include a patent, a European Utility model, an industrial design right, or a trademark. This indicator is a proxy for whether a business has developed an innovation that satisfies a set of objective standards as opposed to just being new to the firm: for instance, an invention is patentable if it is novel within a field, non-obvious, and applicable.[20,21] A similar logic holds with European utility models, industrial design rights and trademarks. The indicator of whether an SME has applied for intellectual property protection is considered as an outcome variable in the eocnometric analysis.

Whether a business has conducted R&D

[19] For the purpose of this analysis, 'innovation behaviour' encompasses the introduction of innovations, the performance of innovation activities (e.g. R&D), but also steps taken to protect or acquire rights to an innovation (e.g. applying for a patent).

[20] Although the precise conditions for patentability can vary across jurisdictions, these three criteria are the most common. For instance, Article 52 of the European Patent Convention specifies that "European patents shall be granted for any inventions, in all fields of technology, provided that they are *new*, involve an *inventive step* and are *susceptible of industrial application*. [emphasis added]" (European Patent Office, 2016).

[21] This indicator carries the obvious caveat that an *application* for intellectual property protection does not guarantee that the relevant innovation satisfies all of the conditions for the granting of intellectual property protection.

R&D is an important innovation input. It is proxied by a dummy variable indicating whether a business has undertaken in-house R&D "to create new knowledge or to solve scientific or technical problems" between 2012 and 2014 (Eurostat, 2014). It should be noted that this covers R&D for the purpose of product and process innovations only. This indicator features in both the descriptive and econometric analysis.

Ongoing innovation activities

Another innovation input measure is whether a business has conducted 'innovation activities'[22] that were still ongoing in 2014. Given that ongoing innovation activities have presumably not yet materialized, these are less likely to have impacted firm performance. Hence, when included as a dependent variable in the econometric analysis, this variable is expected to be less prone to simultaneity bias (reverse causality) than the indicator of whether a business has introduced an innovation between 2012 and 2014 (in other words, ongoing innovation is less likely to have a causal impact on certain explanatory variables of interest such as turnover growth – see below for a list of the explanatory variables). It is therefore used to check the robustness of the baseline econometric models.

R&D pattern

Businesses that have engaged in in-house R&D (for product or process innovations) may have done so on a continuous or occasional basis. To gain insights about the pattern in SMEs' innovation activities, the econometric analysis considers an indicator for whether a business has permanent staff dedicated to R&D or whether R&D is conducted "as needed only" (Eurostat, 2014). This indicator is considered as an outcome variable in the econometric analysis.

Barriers faced by non-innovators

To gain insight into some of the reasons why businesses may not have engaged in innovation activities, both the descriptive and econometric analysis explore potential barriers to innovation faced by SMEs between 2012 and 2014.[23] This information is only available for businesses that considered innovating but did not conduct any innovation activities because of obstacles to innovation (i.e. this variable is not populated for businesses which had no need for innovation). The following barriers are considered (Eurostat, 2014):

- "Lack of internal finance for innovation";
- "Lack of credit or private equity";
- "Lack of skilled employees within [the] enterprise";
- "Difficulties in obtaining government grants or subsidies for innovation";
- "Lack of collaboration partners";
- "Uncertain market demand for [business's] ideas for innovations";
- "Too much competition in [business's] market".

In the survey, respondents can attach either no importance, low importance, medium importance or high importance to each of these barriers. For each problem, two binary variables are derived from these responses. The first indicates whether a given barrier has high importance, as opposed to no, little or medium importance. The second takes the value of 1 if a given barrier was given low, medium or high importance, and 0 otherwise.

Firm characteristics

[22] This covers: "the acquisition of machinery, equipment, buildings, software, and licenses; engineering and development work, feasibility studies, design, training, R&D and marketing when they are specifically undertaken to develop and/or implement a product or process innovation. This includes also all types of R&D consisting of research and development activities to create new knowledge or solve scientific or technical problems."

[23] In the econometric analysis, bariers to innovation are included as dependent variables.

Number of employees
Information on average number of employees in 2014[24] is available is available through a categorical variable indicating size classes. The granularity of employee size class breakdowns varies across countries. While Slovak businesses are only broken down into SMEs and large companies, Bulgaria, Germany and Romania offer the most granular classification: 10-49, 50-249, 250-499, and over 500 employees. All other eight countries break down employee size class into three bands: 10-49, 50-249, and over 250 employees. For the purpose of the econometric analysis, employee size classes were broken down into three bands (10-49, 50-249, and over 250 employees) in order to maximize geographical coverage while still allowing to control for size. Slovak businesses are therefore not considered in the econometric analysis. They are, however, considered in the first two components of the descriptive analysis, which only require to distinguish SMEs from large companies.

Turnover
Turnover is a proxy for size, a potential driver of innovation. Turnover is defined in the questionnaire as "the market sales of goods and services ([including] all taxes except VAT[25])" (Eurostat, 2014). The scientific-use files contain turnover in 2014 as well as growth in turnover between 2012 and 2014. Turnover in 2012 was derived based on these two variables.[26] Both turnover in 2012 and 2014 were recoded into binary variables indicating ranges: up to €500,000, €500,000-1,000,000, €1,000,000-2,000,000, €2,000,000-10,000,000, €10,000,000-50,000,000, and over €50,000,000.

In the scientific-use files, turnover data was perturbed through micro-aggregation for confidentiality purposes. This can bias coefficients in regression analysis (Eurostat, 2017; Ronning et al., 2005). Hence, most econometric models do not include turnover as an explanatory variable. Nevertheless, only a small number of records were affected, so the bias is likely to be minor unless analysis is performed on small sub-samples (Eurostat, 2017). Robustness checks are therefore run with turnover range indicators included as explanatory variables in order to verify whether results change markedly.

Sector
The economic activity of businesses based on the NACE Rev. 2 classification. Sector is an explanatory variable in the econometric analysis and is used to classify businesses in the descriptive analysis. For the purpose of the econometric analysis, the following sectors are defined: industry (NACE Rev. 2 sections B, D-F), manufacturing (section C), trade (section G), services (sections H-N, Q, R, U).

Growth
The econometric analysis includes categories of turnover and employment growth as explanatory variables. Each of these variables refers to growth between 2012 and 2014 (i.e. over three years) and is categorized into eight bands: negative growth of 100% to 70%, 70% to 40%, 40% to 10%, stable turnover or employment (-10% to 10%), and positive growth ranging from 10% to 40%, 40% to 70%, 70% to 100%, or greater than 100%. Growth can be thought of as a proxy for a firm's dynamism. In addition, high employment growth may lead to an influx of skills and new ideas that may drive innovation behaviour.

Legal status
Another explanatory variable in the econometric analysis is an indicator of whether an SME is part of a group, i.e. one of several "legally defined enterprises under common ownership" (Eurostat, 2014).

Export activity

[24] If an annual average is not available, the harmonised survey questionnaire recommends reporting the number of employees at the end of the year (Eurostat, 2014).
[25] "For Credit institutions: Interests receivable and similar income; for Insurance services: [...] gross premiums written."
[26] Turnover growth is rounded to the nearest 10%. Hence, the 2012 turnover growth figures are approximations.

To capture the potential effect of export behaviour on innovation activity, the econometric analysis includes a dummy variable for whether a business has exported in 2012. This binary variable is derived from reported export intensity.

Although the dataset also contains a categorical proxy for export behaviour which is more populated than export intensity[27], its reference period is 2012-2014. Given that innovation is likely to impact whether a business exports, using a variable with reference period 2012-2014 is likely to increase the risk of simultaneity bias (reverse causality) compared to using the export indicator based on the year 2012.

7.4 Descriptive analysis

The descriptive analysis comprises three parts. The first compares innovation behaviour indicators in large companies and SMEs across various sectors. The second considers the barriers faced by non-innovating SMEs. The third provides a descriptive analysis of the econometric analysis sample.

7.4.1 Relative performance of SMEs and large companies – by sector

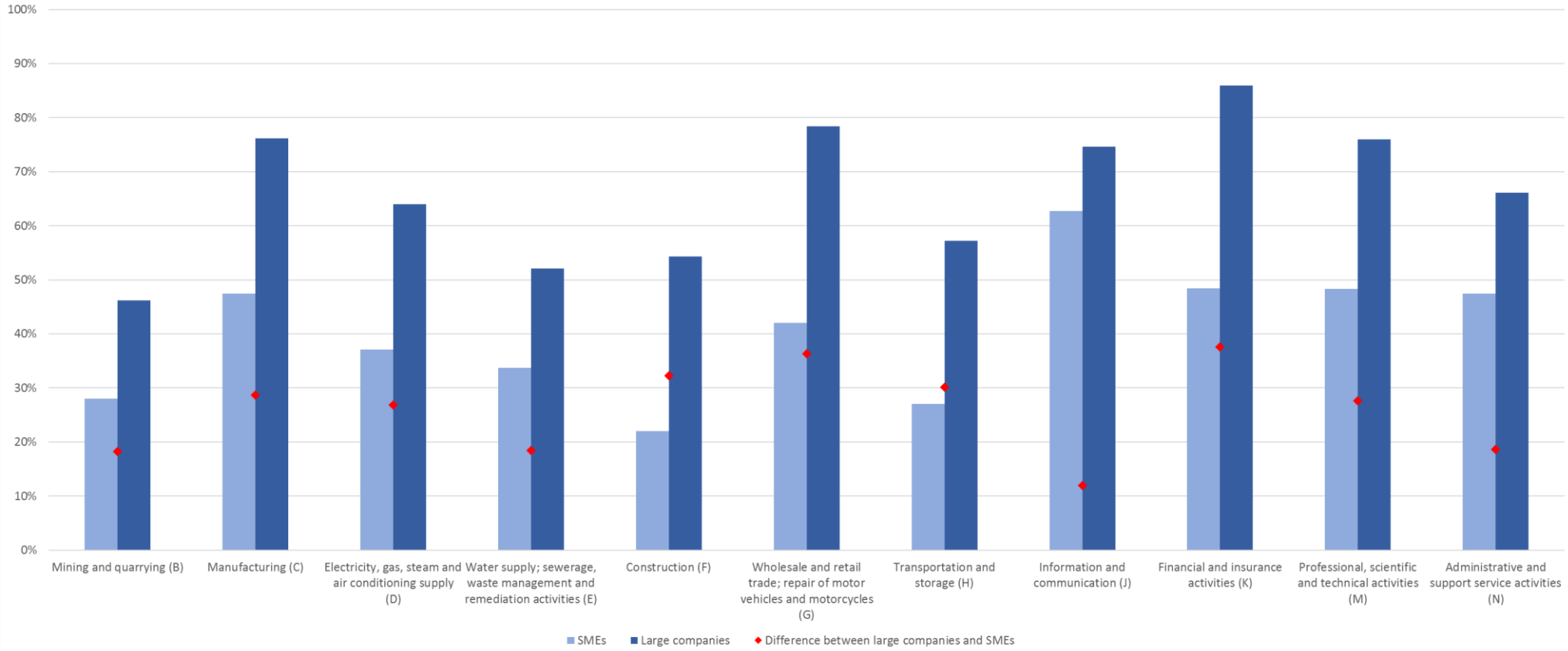
The present analysis compares the innovation behaviour of SMEs and large companies within different NACE Rev. 2 sections. Key indicators are the proportion of businesses that have innovated between 2012 and 2014[28] or the 'innovation rate', and the proportion of enterprises that conducted in-house R&D between 2012 and 2014 (or the share of 'R&D active' firms). This analysis is weighted and covers businesses from Bulgaria, Croatia, Czechia, Estonia, Germany, Greece, Hungary, Latvia, Lithuania, Portugal, Romania and Slovakia.[29]

As illustrated by Figure 16, the gap between the shares of innovators among SMEs and among large companies is the largest in financial and insurance activities (section K) and trade (section G). In the construction, and transportation and storage sectors (sections F and H), the proportion of innovators is more than twice as high in large companies as in SMEs.

The difference in the proportions of innovating SMEs and large companies is lowest in the information and communication sector (section J), where both a large share of SMEs and large companies have innovated between 2012 and 2014.

[27] This is based on indicators of the markets in which businesses sold their goods or services.
[28] This may be either a product, process, organisational or marketing innovation.
[29] It should be noted that the proportions obtained are not directly comparable to published figures, which do not match weighted aggregates from the microdata in every country. For instance, the weighted total number of enterprises (across all sectors) differs in the case of Germany, Estonia, Greece, Lithuania, Hungary and Portugal. These discrepancies are partially due to the fact that, for some Member States, not all sectors that feature in the micro-data are included in published figures.

Figure 16 Share of innovators in large companies and SMEs – by sector



Note: Number of observations: 284672 (weighted). NACE Rev. 2 sections are included in brackets. This analysis considers whether businesses have introduced any innovation between 2012 and 2014 (i.e. product, process, organisational or marketing).

Source: LE Europe analysis of the Community Innovation Survey 2014

Figure 17 suggests that the disparity between the shares of SMEs and large businesses that have conducted R&D is widest in manufacturing (section C), mining and quarying (section B), and trade (section G). In the latter two cases, the share of large companies engaged in R&D is more than twice as large as the proportion of SMEs that are R&D active.

The two sectors in which the gap between SMEs and large companies is lowest each have the highest and some of the lowest shares R&D active businesses. On one hand, Administrative and support service activities (section N) has the lowest share of large companies undertaking R&D and the second lowest share of R&D active SMEs (after transportation and storage). On the other hand, the information and communication sector (section J) has by far the largest share of SMEs undertaking R&D, as well as the highest percentage of R&D active large companies.

Figure 18 allows for a comparison between the shares of R&D active and innovative businesses. For comparability with Figure 17, the analysis is run on the same set of businesses,[30,31] and only considers product and process innovation activities.

In almost all sectors, innovation rate is higher than the share of businesses that conducted R&D, both for SMEs and large companies.[32] This reflects the fact that innovations may sometimes result from R&D that was not conducted in-house (e.g. it may have been outsourced or undertaken by collaboration partners) or may not even require R&D.

The absolute difference[33] between the proportions of R&D active SMEs and large companies is larger than the gap in innovation rates in manufacturing (C), electricity, gas, steam and air conditioning supply (D), trade (G), financial and insurance activities (K), and professional, scientific and technical activities (M), and lower in other sectors.[34] As such, there is no clear pattern when comparing absolute gaps.

The relative gap between the proportion of R&D active SMEs and large companies is generally larger than the relative difference in the innovation rates.[35]

[30] Restricting the analysis sample to businesses that have answered both the questions on in-house R&D activities and product or process innovation has the disadvantage that the analysis may not be as representative of the population if non-response to the question on in-house R&D activities is not randomly distributed. This is of particular concern given that the (unweighted) number of respondents that have answered the questions on product and process innovations is more than three times larger than the number of firms that have also answered the questions about in-house R&D activities.

[31] Note that some additional sectors were omitted from the analysis in Figure 18 for confidentiality reasons.

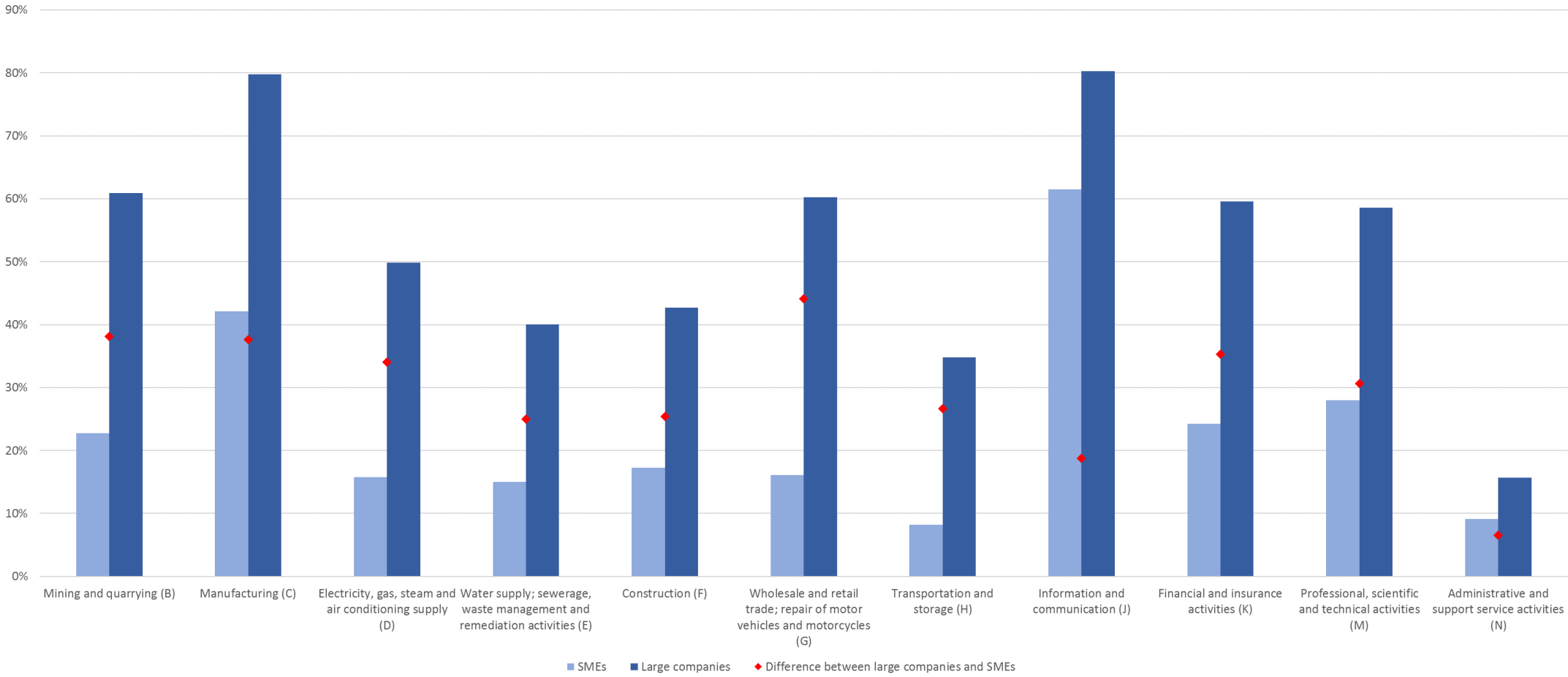
[32] The only exception is administrative and support service activities (section N).

[33] The relative difference is defined as follows: $relative\ difference = \frac{innovation\ rate_{LC} - innovation\ rate_{SME}}{innovation\ rate_{SME}}$. This compares to the absolute difference, which is defined as $absolute\ difference = innovation\ rate_{LC} - innovation\ rate_{SME}$.

[34] On average, the absolute gap is larger when considering the innovation rate than the share of R&D active businesses.

[35] Presumably, this is at least in part due to the fact that the share of businesses conducting R&D is lower than the innovation rate, which implies a lower baseline when considering the relative difference.

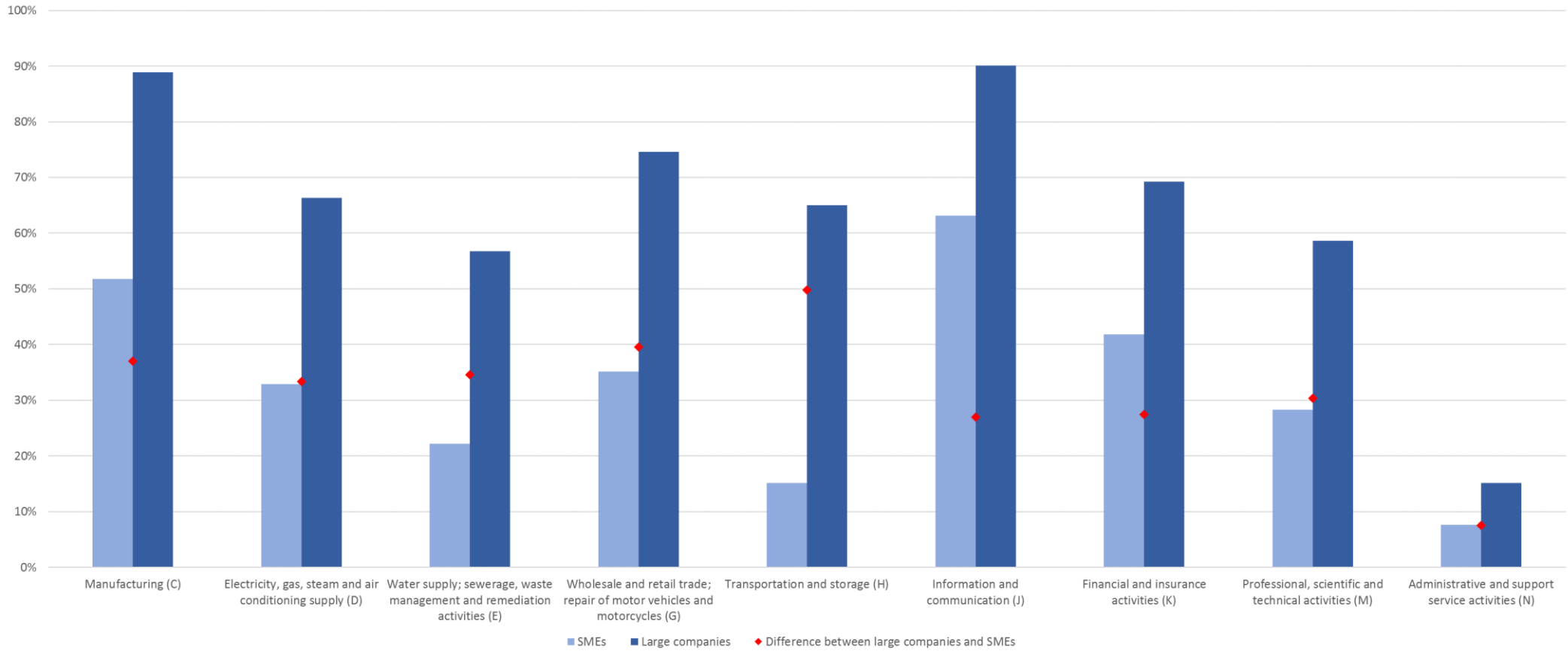
Figure 17 Share of large companies and SMEs conducting in-house R&D – by sector



Note: Number of observations (weighted): 154265. NACE Rev. 2 sections are included in brackets. This analysis considers whether businesses have undertaken in-house R&D between 2012 and 2014 for product or process innovations.

Source: LE Europe analysis of the Community Innovation Survey 2014

Figure 18 Share of product and process innovators in large companies and SMEs – by sector



Note: Number of observations (weighted): 152867. NACE Rev. 2 sections are included in brackets. This analysis considers whether businesses have introduced a product or process innovation between 2012 and 2014.

Source: LE Europe analysis of the Community Innovation Survey 2014

7.4.2 Barriers faced by non-innovators

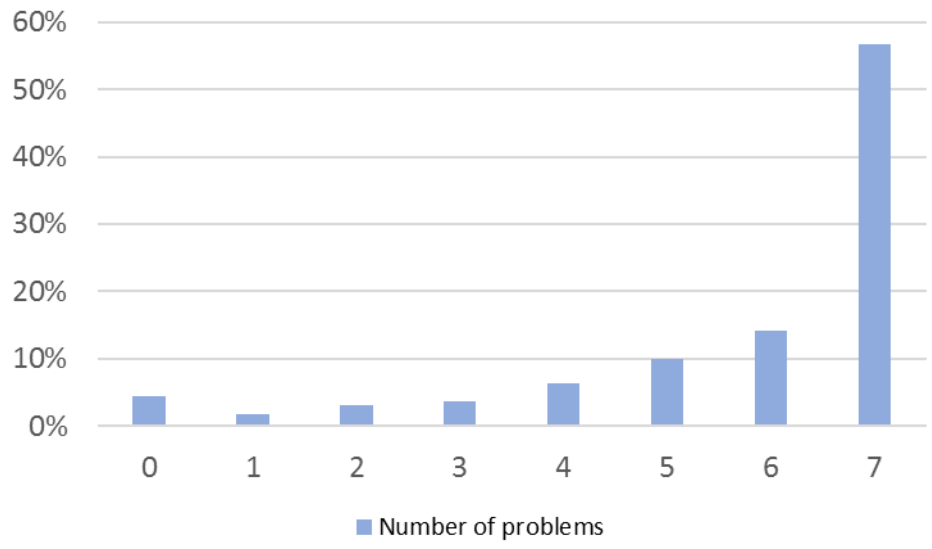
This section considers the barriers to innovation faced by SMEs that did not innovate.[36] This analysis is weighted and includes businesses from Bulgaria, Croatia, Czechia, Estonia, Greece, Hungary, Latvia, Lithuania, Portugal, Romania and Slovakia. Furthermore, the sample is restricted to SMEs that considered innovating but that did not do so because obstacles were too high.[37]

Figure 19 shows that the vast majority of non-innovating SMEs accord some importance to at least one of the barriers listed in the survey. Furthermore, over half of SMEs attach some importance to all seven of the barriers.

On the other hand,when considering only barriers that are given high importance, a much larger proportion of non-innovating SMEs report facing no or few of the barriers: more than one quarter of SMEs accord high importance to none of the problems listed in the survey and more than 15% only cited only one of the problems as highly important (Figure 20). Still, the majority non-innovating SMEs accord high importance to at least one of the barriers listed in the survey, and among these, over three quarters face more than one barrier.[38]

Together, Figure 19 and Figure 20 suggest that there are two potential factors hindering innovation. The first is high importance barriers (these could be thought of as 'high intensity' barriers) which tend to rarely rarely occur in sets of more than three. The second phenomenon is the combination of multiple low to medium importance or 'moderate intensity' barriers which together impede innovative activity. The latter phenomenon is illustrated by Figure 21, which shows that almost half of the SMEs that do not face any highly important barrier face seven low or medium importance barriers.

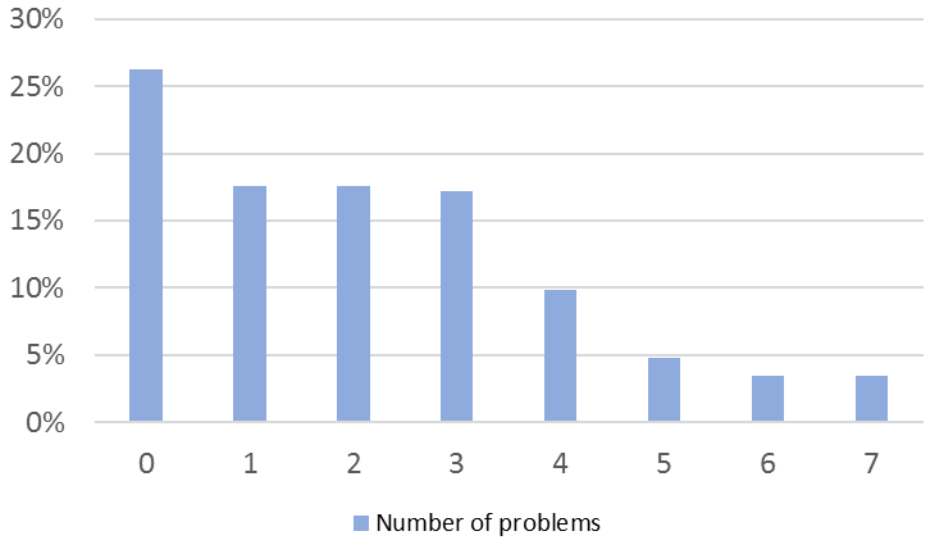
Figure 19 Distribution of non-innovating SMEs by number of barriers faced (low, medium or high importance)



Note: Number of observations (weighted): 13125.
Source: LE Europe analysis of the Community Innovation Survey 2014

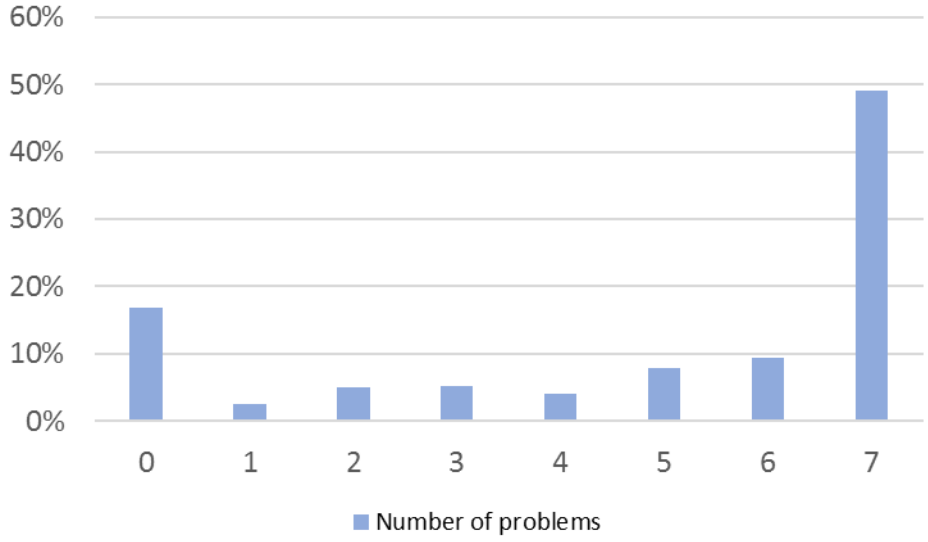
[36] For concision, these SMEs are referred to as 'non-innovators', but it should be noted that these do not include SMEs that did not innovate for other reasons than high barriers (e.g. no need for innovation).
[37] In fact, the analysis is retricted to SMEs that did not conduct any *innovation activities* (e.g. SMEs that did not innovate but that conducted R&D are not considered).
[38] 74% of SMEs face at least one barrier and 56% face more than one barrier. Hence, the frequency of SMEs facing more than one barrier, conditional on facing at leat one barrier is 76%.

Figure 20 Distribution of non-innovating SMEs by number of barriers faced (high importance)



Note: Number of observations (weighted): 13125.
Source: LE Europe analysis of the Community Innovation Survey 2014

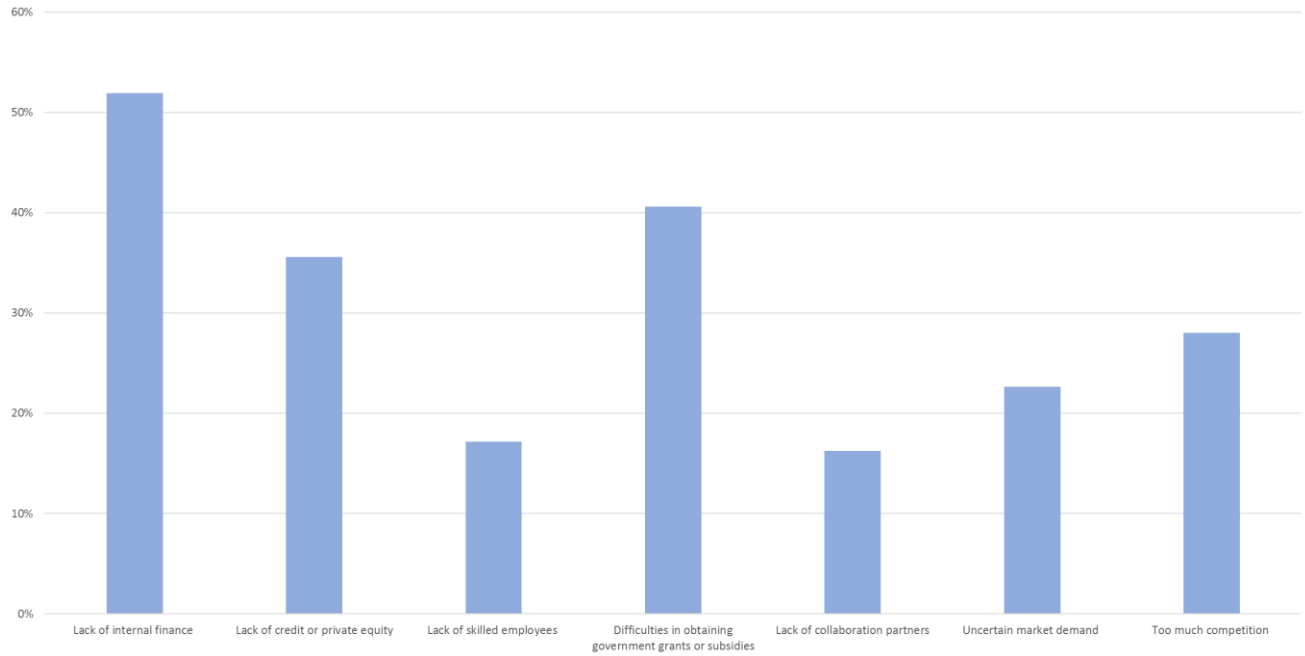
Figure 21 Distribution of non-innovating SMEs by number of barriers faced (conditional on no highly important barrier)



Note: Number of observations (weighted): 3442.
Source: LE Europe analysis of the Community Innovation Survey 2014

Figure 22 suggests that, among barriers that have high importance, those related to funding are the most ubiquitous: more than 50% of SMEs accord high importance to lack of internal finance. More than 40% face important difficulties in obtaining government grants or subsdies, and approximately 35% face a lack of credit or private equity.

Figure 22 Share of non-innovating SMEs facing various barriers to innovation (high importance)



Note: Number of observations (weighted): 13125.
Source: LE Europe analysis of the Community Innovation Survey 2014

Table 18 investigates how various barriers are associated with one another among non-innovating SMEs (only barriers that are given high importance are considered). Each percentage denotes the frequency of the barrier listed on the column, conditional on the barrier listed on the row being highly important. For example, the third cell in the first row represents SMEs that report lack credit or private equity is a high barrier as a share of all SMEs that report lack collaboration partnersas a high barrier.

The barrier lack of internal finance almost always has the highest conditional frequency. It is generally followed by the barriers difficulties in obtaining government grants or subsidies, and lack of credit or private equity. This is in line with the unconditional frequencies described in Figure 22:access to finance is the most prevalent obstacle.

An exception to this pattern is the incidence of the barrier excessive competition, conditional on uncertain market demand for a firm's ideas for innovation. Indeed, at 61% the conditional frequency of 'too much competition' is higher than that of 'lack of credit or private equity' and almost as high as those of the other two barriers related to funding. Unlike the other barriers that are listed in the survey (i.e. access to finance, skills and collaboration partners), which can be understood as innovation 'supply shifters', competition and uncertain demand are mostly demand-related, so it is not surprising that these are more closely related to one another.

Table 18 Associated pairs of barriers to innovation (high importance)

	Lack of collaboration partners	Too much competition	Lack of credit or private equity	Uncertain market demand	Difficulties in obtaining government grants or subsidies	Lack of internal finance	Lack of skilled employees
Lack of collaboration partners	100%	58%	61%	61%	73%	73%	47%
Too much competition	34%	100%	53%	49%	61%	69%	30%
Lack of credit or private equity	28%	42%	100%	34%	65%	88%	27%
Uncertain market demand	43%	61%	54%	100%	64%	65%	34%
Difficulties in obtaining government grants or subsidies	29%	42%	57%	36%	100%	74%	27%
Lack of internal finance	23%	37%	60%	28%	58%	100%	23%
Lack of skilled employees	44%	49%	55%	45%	64%	70%	100%

Note: Number of observations (weighted): 9683. This analysis considers only non-innovating SMEs that face at least one of the above barriers to innovation. Frequencies are conditional on the row barrier being relevant. Only barriers of high importance are considered.

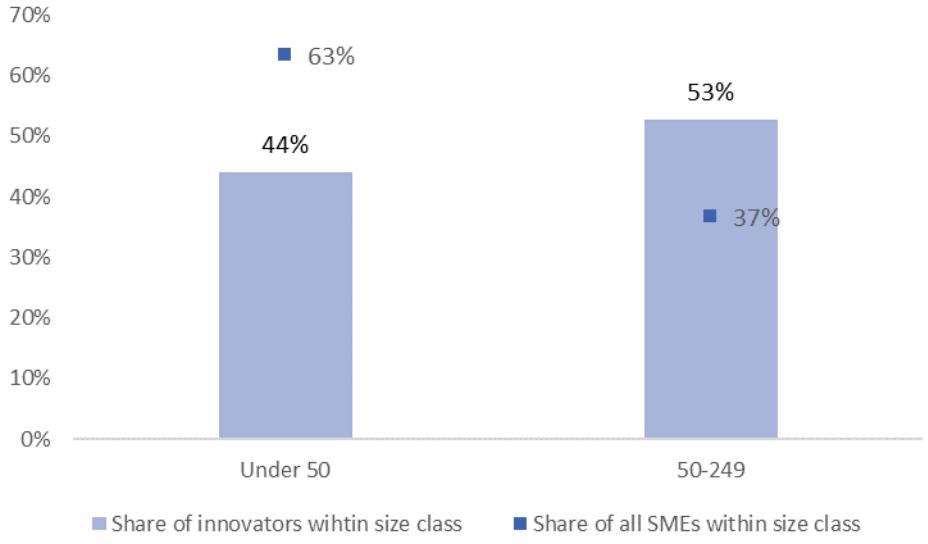
Source: LE Europe analysis of the Community Innovation Survey 2014

7.4.3 Econometric analysis - sample characteristics

The following analysis describes the sample of SMEs that is used for the baseline econometric analysis (i.e. model (1)), which directly follows in the next section. The analysis considers both the share of SMEs that have introduced an innovation between 2012 and 2014 within each employee size class, sector and country, and the distribution of all SMEs across these categories. The econometric analysis uses unweighted data.

Figure 23 shows that, within the sample, the proportion of innovators is larger among medium-sized enterprises (50-249 employees) than among small SMEs (10-49 employees). The split between small and medium-sized SMEs (both innovators and non-innovators) is approximately 60-40.

Figure 23 Share of innovating SMEs, by employee size class

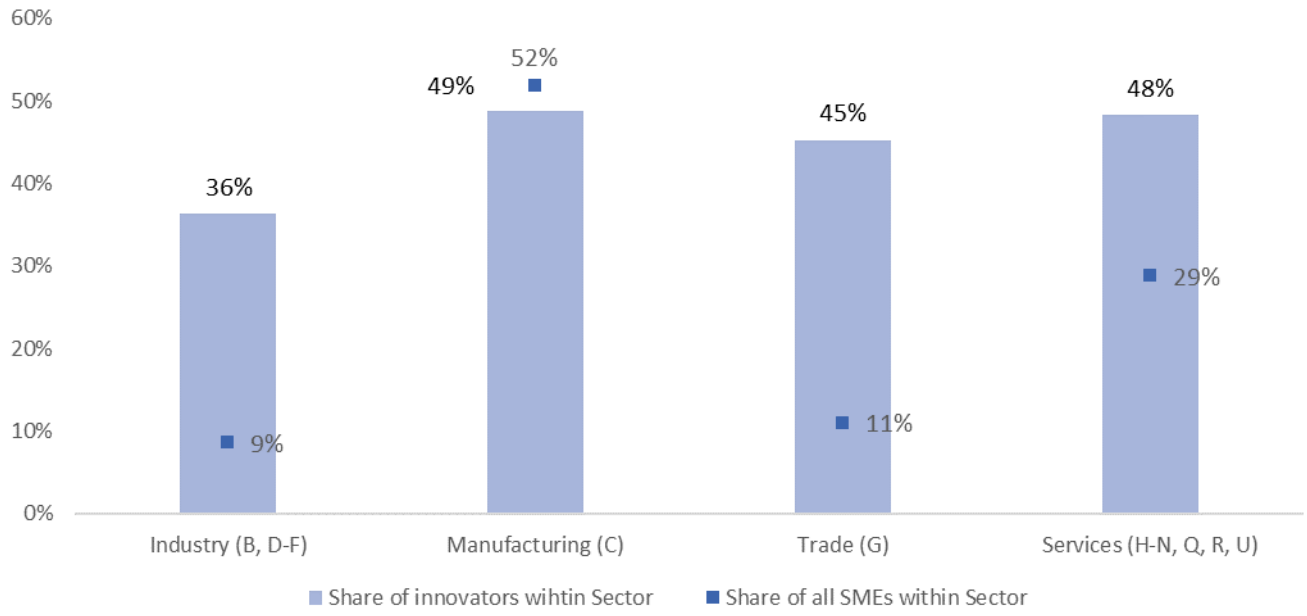


Note: Number of observations: 27446.

Source: LE Europe analysis of the Community Innovation Survey 2014

As indicated in Figure 24, the share of innovating SMEs is largest in the manufacturing and services sectors, which account for over 80% of the sample. Industry, which makes up less than 10% of the sample, also has the lowest share of innovating SMEs.

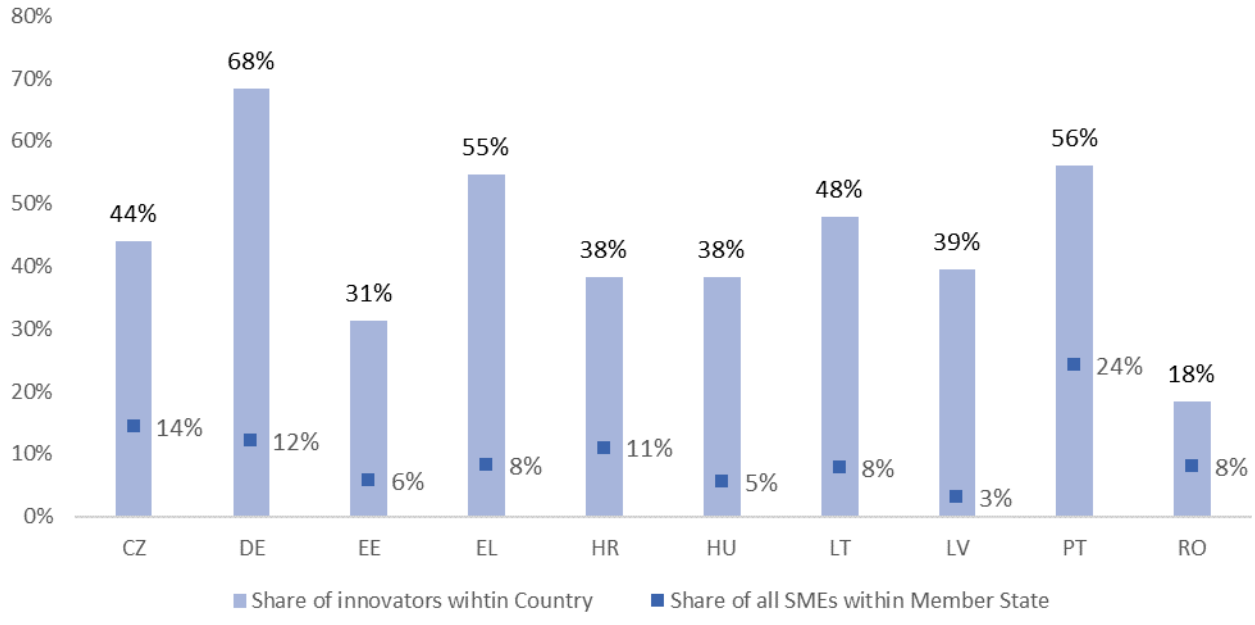
Figure 24 Share of innovating SMEs, by sector



Note: Number of observations: 27446. Sectors are based on the Nace Rev. 2 classification.
Source: LE Europe analysis of the Community Innovation Survey 2014

There are larger disparities in the shares of innovators across countries than across sectors and employee size classes. Germany, Portugal and Greece have the largest shares of innovating SMEs, while Romania and Estonia have the lowest.

Figure 25 Share of innovating SMEs, by Member State



Note: Number of observations: 27446.
Source: LE Europe analysis of the Community Innovation Survey 2014

7.5 Econometric analysis

7.5.1 Innovation behaviour and firm characteristics

Baseline

The first part of the econometric analysis explores how firm characteristics predict innovation behaviour. Key indicators are whether an SME has innovated between 2012 and 2014 (models (1) and (2)), whether it has applied for intellectual property protection in that period (model (3)) and whether it has conducted R&D between 2012 and 2014 (model (4)). The econometric analysis uses unweighted data.

The explanatory variables included in the model are all binary. These include indicators of sector, employment size classes, legal status (i.e. whether the respondent is part of an enterprise group), whether the business exported in 2012, turnover growth (coded in ranges, as explained above), and employment growth (also coded in ranges).

Member State dummies were aded to the model in order to control for potential country-level factors that could influence both firms' propensity to innovate and some of the other variables of interest.[39] Standard errors were clustered at the Member state level to account for potential correlation of unexplained factors across SMEs within countries.[40]

Each of the models has a fairly low pseudo R-squared. Furthermore, Hosmer and Lemeshow tests presents evidence against the null hypotheses that models (3) and (4) are correct – results from these models should therefore be interpreted with caution.

Results are reported as odds ratios. These express how the odds of the outcome (i.e. engaging in innovation behaviour) differ across SMEs with different characteristics (e.g. sector): specifically, the odds ratios for each characteristic are relative to a chosen baseline caregory (see notes under regression tables).

Most odds ratios for the sector indicators are greater than 1, which indicates that the odds of innovating, conducting R&D or applying for intellectual property protection are higher among SMEs operating in the manufacturing, trade or services sectors, compared to industry (the baseline category). In all models except for model (3), SMEs in the manufacturing and services sectors are more likely to engage in innovation behaviour than those in wholesale and retail trade.[41] In model (3), SMEs engaged in trade have a higher propensity to apply for intellectual property protection than businesses in industry but also services, although in the latter case, the difference in odds ratios is not statistically significant.

In all models, medium-sized SMEs are more likely to engage in innovative behaviour, and businesses that are part of an enterprise group are more likely to engage in innovative behaviour. Businesses that have exported at the beginning of the reference period are more likely to engage in innovative behaviour.

Overall, growing SMEs are more likely to innovate. There is less evidence of a link between growth and other types of innovation behaviour (namely in-house R&D and applications for intellectual property).

[39] Models explaining whether SMEs innovated between 2012 and 2014 were fitted both with and without country dummies via seemingly unrelated estimation. Hypothesis tests indicated that a number of coefficients were different. These included the coefficient on the export indicator as well as most of the coefficients on the employment growth range indicators.

[40] The estimation samples include SMEs from Czechia (except in the model explaining applications for intellectual property), Germany, Estonia, Greece, Croatia, Hungary, Lithuania, Latvia, Portugal and Romania.

[41] In model (1), the difference is only statistically significant (5% level) when comparing trade to services. In model (2), both differences are statistically significant (at the 1% level). In model (3), none of the coefficients are statistically significantly different. In model (4), both differences are statistically significant at the 1% level.

Columns (1) and (2) in Table 19 uggest that SMEs with positive turnover growth are more likely to innovate whereas businesses with declining turnover are less likely to innovate. Indeed, the odds ratios associated with negative growth indicators are lower than 1 while those associated with positive growth indicators are greater than 1. Most odds ratios on the turnover indicators are not statistically significant in the models explaining intellectual property applications and in-house R&D (models (3) and (4)).

A similar pattern holds with employment growth. Although three of the odds ratios are not statistically significant in models (1) and (2), odds ratios associated with negative employment growth bands are lower than 1, indicating a lower propensity to innovate, and those associated with positive employment growth ranges are greater than 1, indicating a higher propensity to innovate. In models (3) and (4), odds ratios associated with negative employement growth bands are not statistically significant, while those attached to positive employment growth bands are greater than 1.[42]

[42] It should be noted, however, that (i) the relative magnitudes of the odds ratios suggest that there may be some non-monotonicities in this relationship (e.g. the odds ratios attached to employment growth of over 100% has a lower magnitude than the odds ratio for employment growth of 40%-70%, although the difference is not statistically significant) and (ii) the differences between odds ratios attached to consecutive growth ranges are usually not statistically significant. Therefore, although results suggest that growing SMEs are more likley to innovate and SMEs with negative growth are less likely to innovate, there is little evidence of clear monotonic (positive) relationship between growth and innovation.

Table 19 Innovation behaviour and firm characteristics

Odds ratios	(1)	(2)	(3)	(4)
	Innovation	***Product/process innovation***	***Intellectual property***	***In-house R&D***
Sector				
Manufacturing (C)	1.521***	1.704***	3.343***	2.276*
	(0.224)	(0.321)	(1.154)	(0.953)
Trade (G)	1.381***	1.171	3.062***	1.170
	(0.143)	(0.165)	(0.428)	(0.266)
Services (H-N, Q, R, U)	1.530***	1.605***	2.761***	2.532***
	(0.160)	(0.248)	(0.418)	(0.533)
Number of employees				
50-249 employees	1.524***	1.518***	1.501***	1.376***
	(0.102)	(0.102)	(0.079)	(0.121)
Administrative status				
Part of a group	1.659***	1.490***	1.291**	1.265**
	(0.108)	(0.085)	(0.154)	(0.136)
Export behaviour				
Exporter (2012)	1.510***	1.585***	1.994***	1.728***
	(0.060)	(0.092)	(0.143)	(0.060)
Turnover growth				
-100%/-70%	0.532***	0.541***	0.515**	1.352
	(0.083)	(0.098)	(0.170)	(0.642)
-70%/-40%	0.776***	0.724***	0.936	1.328***
	(0.069)	(0.085)	(0.079)	(0.136)
-40%/-10%	0.905***	0.872***	0.901	1.115
	(0.026)	(0.034)	(0.080)	(0.081)
10%/40%	1.190***	1.145***	1.102	1.071
	(0.062)	(0.057)	(0.081)	(0.104)
40%/70%	1.183**	1.150***	1.279***	1.187*
	(0.091)	(0.041)	(0.101)	(0.107)
70%/100%	1.258***	1.287***	1.058	1.215
	(0.105)	(0.081)	(0.119)	(0.176)
over 100%	1.189*	1.135	1.257	1.284
	(0.113)	(0.142)	(0.252)	(0.221)
Employment growth				
-100%/-70%	0.906	0.847	0.874	1.044
	(0.332)	(0.255)	(0.620)	(0.770)
-70%/-40%	0.781*	0.579***	0.970	0.828
	(0.101)	(0.093)	(0.237)	(0.147)
-40%/-10%	0.884***	0.861***	1.006	0.872
	(0.039)	(0.033)	(0.075)	(0.082)
10%/40%	1.231***	1.237***	1.364***	1.160***
	(0.036)	(0.032)	(0.031)	(0.040)
40%/70%	1.205*	1.237**	1.403***	1.209**
	(0.117)	(0.104)	(0.097)	(0.092)
70%/100%	1.108	1.094	1.467***	1.372*
	(0.101)	(0.131)	(0.127)	(0.249)
over 100%	1.146	1.073	1.557***	1.014
	(0.098)	(0.094)	(0.242)	(0.160)
Country dummies	Yes	Yes	Yes	Yes
Number of observations	27446	27782	23454	11485
Pseudo R-squared	0.088	0.093	0.084	0.055
Hosmer and Lemeshow (p-value)	0.2438	0.5185	0.0243	0.0115

**p<0.1, **p<0.05, ***p<0.01*

Note: Standard errors in parentheses. Baseline categories are: Industry (NACE Rev. 2 sections B/D-F), 10-49 employees, growth between -10% and 10% (in turnover/the number of employees).

Source: LE Europe analysis of the Community Innovation Survey 2014

Robustness

It is possible that innovation behaviour (the dependent variable) determines some of the explanatory variables. In particular, innovation is presumably a causal driver of turnover and employment growth. This is of particular concern because the reference period for each of the innovation indicators used in the baseline specification is 2012-2014, which means that these indicators could, for instance, refer to an innovation conducted in 2012, which may have led to an increase in turnover in 2013 or 2014, and therefore to growth in turnover across the reference period. A similar logic applies to employment and export behaviour (although, this is less of a concern with the export indicator, which is based on the year 2012). Because of this, there is a risk that the estimated odds ratios on certain explanatory variables are biased: this is referred to as simultaneity bias.

Therefore, as a robustness check, a regression was run using an indicator for whether SMEs had innovation activities that did not result in a product or process innovation because they were still ongoing in 2014.[43] Because these activities did not result in new or improved products or processes by 2014, they are less likely to have affected firm growth or 2012 exports and hence, estimates should not be subject to simultaneity bias.[44] The estimation results are reported in Table 20

Results from model (5) are broadly similar to those in the baseline models. SMEs in manufacturig and services have a higher propensity to be engaged in innovation activities than those in industry or trade.[45] Medium-sized enterprises are more likely to have ongoing innovation activities than small SMEs. Businesses that are part of a group or that exported in 2012 are more likely to have ongoing innovation activities that did not result in a product or process activity by the end of 2014.

Less than half of the odds ratios on turnover growth bands are statistically significant, although these are all associated with positive growth bands and are greater than 1, which suggests that SMEs with growing turnover have a higher propensity to innovate than SMEs with stable turnover (between -10% and 10%). There is less evidence that SMEs with negative turnover growth have a lower propensity to innovate (odds ratios are lower than 1 but not statistically significant).

The odds ratios on employment growth suggest that growing SMEs have a higher propensity to innovate whereas SMEs with declining employment are less likely to innovate, which is consistent with the findings from models (1), (2) and, to some extent, model (3).

An additional concern is that innovation behaviour may also impact the number of employees (i.e. the level rather than growth in employment). The scientific-use files only contain employment categories based on 2014, so it is not possible to control for employment at the start of the reference period. One of the robustness checks described below uses an alternative measure of size (turnover) in 2012 instead of employment size class.

Two additional robustness checks were conducted. The first includes turnover in 2014 as an explanatory variable and whether a firm has innovated between 2012 and 2014 as a dependent variable.[46] The general findings from model (6) remain similar to those of model (1), with the odds ratios on turnover ranges indicating a positve relationship between

[43] The estimation sample includes SMEs from Czechia, Germany, Estonia, Greece, Croatia, Hungary, Lithuania, Latvia, Portugal and Romania.
[44] Results from this robustness check (model (5)) are not directly comparable to any single one of the baseline models for several reasons. First, the outcomes in the baseline models are different to that in model (5), which captures a range of innovation activities rather than actual innovations, applications for intellectual property protection, or R&D (namely, the outcomes of models (1), (2), (3) and (4)). Second, ongoing innovation activity is an imprefect proxy for innovation behaviour (e.g. if an SME inroduced an innovation in 2014 but had no ongoing innovation activties at the end of the year, the dependent variable in model (5) would be coded as 0, even though the respondent is an innovator).
[45] The difference is statistically significant at the 1% level.
[46] The estimation sample includes SMEs from Czechia, Germany, Estonia, Greece, Croatia, Hungary, Lithuania, Latvia, Portugal and Romania.

turnover (and therefore size) and propensity to innovate.[47] Notable differences between the two models include a smaller odds ratio attached to employment size class: this is consistent with the fact that both employment and turnover capture size. Although the odds ratios on sector indicators are different across both models, their relative magnitudes are similar to those in model (1): businesses in manufacturing and services are more likely to innovate than those in trade,[48] which in turn are more likely to innovate than SMEs in industry. As in model (1), businesses that are part of a group and that have exported in 2012 are more likely to have innovated. In line with model (1), model (6) also suggests that growing SMEs are more likely to innovate than SMEs with stable or declining employment or turnover.

The second robustness check includes turnover in 2012 as the only proxy for size and whether a firm has innovated between 2012 and 2014 as a dependent variable.[49] The objective of this check is to use a size proxy that was determined at the beginning of the reference period and therefore less likely to be affected by any innovations introduced between 2012 and 2014 (there nevertheless still remains the risk that innovations introduced in 2012 may have affected turnover in 2012). The odds ratios are very similar to those in model (6) – including those on turnover – which suggests that any simultaneity bias is minor if existent at all.[50]

[47] The differences between consecutive turnover ranges are statistically significant in all cases at the 5% or 1% level.
[48] The differences are statistically significant at the 1% level.
[49] The estimation sample includes SMEs from Czechia, Germany, Estonia, Greece, Croatia, Hungary, Lithuania, Latvia, Portugal and Romania.
[50] Although robustness checks (5) and (7) are unlikely to be prone to reverse causality, it should be noted that they would not account for some potential omitted variables (e.g. past innovation could lead to high growth or turnover, but also contemporaneous innovation). Furthermore, it should be remembered that turnover data was perturbed, so the results from the latter two robustness tests may carry some bias, as explained earlier. Hence, the results from models (1) to (7) should still be interpreted with some caution.

Table 20 Innovation behaviour and firm characteristics (robustness)

Odds ratios	(5)	(6)	(7)
	Ongoing innovation activity	***Innovation - Controlling for turnover (2014)***	***Innovation - Turnover (2012) as a proxy for size***
Sector			
Manufacturing (C)	1.715**	1.688***	1.686***
	(0.410)	(0.247)	(0.254)
Trade (G)	0.963	1.267**	1.213*
	(0.154)	(0.134)	(0.141)
Services (H-N, Q, R, U)	1.694***	1.657***	1.636***
	(0.294)	(0.187)	(0.198)
Number of employees			
50-249 employees	1.446***	1.180**	
	(0.065)	(0.077)	
Administrative status			
Part of a group	1.520***	1.463***	1.480***
	(0.087)	(0.102)	(0.105)
Export behaviour			
Exporter (2012)	1.764***	1.348***	1.365***
	(0.107)	(0.059)	(0.061)
Turnover growth			
-100%/-70%	0.897	0.699**	0.585***
	(0.338)	(0.113)	(0.096)
-70%/-40%	0.848	0.848*	0.702***
	(0.130)	(0.074)	(0.068)
-40%/-10%	0.999	0.931**	0.873***
	(0.069)	(0.028)	(0.027)
10%/40%	1.153**	1.156***	1.210***
	(0.075)	(0.065)	(0.069)
40%/70%	1.199**	1.140*	1.246***
	(0.088)	(0.086)	(0.098)
70%/100%	1.359***	1.201**	1.343***
	(0.115)	(0.098)	(0.125)
over 100%	1.189	1.123	1.399***
	(0.137)	(0.104)	(0.143)
Employment growth			
-100%/-70%	0.566	0.747	0.751
	(0.298)	(0.295)	(0.260)
-70%/-40%	0.510***	0.762**	0.756**
	(0.075)	(0.100)	(0.090)
-40%/-10%	0.786***	0.901**	0.891***
	(0.055)	(0.039)	(0.038)
10%/40%	1.227***	1.241***	1.247***
	(0.060)	(0.040)	(0.039)
40%/70%	1.461***	1.228**	1.242**
	(0.146)	(0.118)	(0.120)
70%/100%	1.413***	1.141	1.163*
	(0.106)	(0.104)	(0.104)
over 100%	1.123	1.214**	1.273**
	(0.094)	(0.101)	(0.124)
Country dummies	Yes	Yes	Yes
Number of observations	27778	27445	27375
Pseudo R-squared	0.113	0.095	0.094
Hosmer and Lemeshow (p-value)	0.2710	0.1377	0.6547

**p<0.1, **p<0.05, ***p<0.01*

Note: Standard errors in parentheses. Baseline categories are: Industry (NACE Rev. 2 sections B/D-F), 10-49 employees, turnover of up to €500,000, growth between -10% and 10% (in turnover/the number of employees).

Source: LE Europe analysis of the Community Innovation Survey 2014

7.5.2 R&D pattern

The second step of the econometric analysis focuses on pattern of SMEs' innovation behaviour. Specifically, the following analysis investigates whether businesses conduct R&D consistently or only occasionally. This is proxied by an indicator of whether an SME had permanent staff in-house dedicated to R&D between 2012 and 2014, as opposed to conducting R&D only as needed. The explanatory variables are the same as above.[51] The estimation results are reported in Table 21.

SMEs in the manufacturing sector are most likely to conduct R&D 'continuously', followed by SMEs in manufacturing, trade, and finally, industry.[52] Medium-sized SMEs are more likely to have permanent R&D staff in-house than Small SMEs. SMEs that are part of an enterprise group, or that have exported are more likely to conduct R&D on a consistent basis.

Most odds ratios associated with turnover growth ranges are not statistically significant, suggesting that the pattern in SMEs' R&D behaviour is not associated with growth in turnover. Although only four of the odds ratio attached to employment growth ranges are statistically significant, they suggest that SMEs with growing employment are more likely to have permanent staff dedicated to R&D than SMEs with stable or declining employment.[53]

[51] The estimation sample includes SMEs from Czechia, Germany, Estonia, Greece, Croatia, Hungary, Lithuania, Latvia, Portugal and Romania.
[52] The coefficients attached to the services and trade sector were statistically significantly different at the 1% level, but the difference in the coefficients on the manufacturing and trade sectors was not statistically significant.
[53] Three of the statistically significant coefficients attached to positive growth rates and are greater than 1, suggesting that SMEs with growing employment are more likely to conduct R&D continuously. The odds ratios for negative growth rates are all lower than one, but only one is statistically significant at the (10% level).

Table 21 R&D pattern and firm characteristics

Odds ratios	**(8)**
	R&D pattern
Sector	
Manufacturing (C)	2.108***
	(0.545)
Trade (G)	1.893***
	(0.369)
Services (H-N, Q, R, U)	3.465***
	(0.829)
Number of employees	
50-249 employees	1.383***
	(0.167)
Administrative status	
Part of a group	1.239***
	(0.096)
Export behaviour	
Exporter (2012)	1.659***
	(0.087)
Turnover growth	
-100%/-70%	0.655
	(0.268)
-70%/-40%	1.482**
	(0.275)
-40%/-10%	1.147
	(0.113)
10%/40%	0.963
	(0.066)
40%/70%	1.032
	(0.103)
70%/100%	0.973
	(0.093)
over 100%	1.060
	(0.111)
Employment growth	
-100%/-70%	0.322
	(0.381)
-70%/-40%	0.758
	(0.139)
-40%/-10%	0.833*
	(0.085)
10%/40%	1.229***
	(0.090)
40%/70%	1.300
	(0.237)
70%/100%	1.850***
	(0.268)
over 100%	1.763***
	(0.264)
Country dummies	Yes
Number of observations	5369
Pseudo R-squared	0.071
Hosmer and Lemeshow (p-value)	0.8369

**p<0.1, **p<0.05, ***p<0.01*

Note: Standard errors in parentheses. Baseline categories are: Industry (NACE Rev. 2 sections B/D-F), 10-49 employees, growth between -10% and 10% (in turnover/the number of employees).

Source: LE Europe analysis of the Community Innovation Survey 2014

7.5.3 Barriers faced by non-innovators

The present analysis investigates whether certain firm characteristics are associated with barriers hindering innovation among SMEs. As mentioned earlier, the barriers that are considered are:

- "Lack of internal finance for innovation";
- "Lack of credit or private equity";
- "Lack of skilled employees within [the] enterprise";
- "Difficulties in obtaining government grants or subsidies for innovation";
- "Lack of collaboration partners";
- "Uncertain market demand for [business's] ideas for innovations";
- "Too much competition in [business's] market".

A logit regression is fitted for each barrier and the dependent variable is an dummy variable that takes the value of 1 if a given barrier is considered highly important by an SME. As illustrated in the descriptive analysis, the barriers faced by non-innovating SMEs tend to not occur in isolation but in 'clusters'. This suggests that the existence of barriers may be correlated with one another. This correlation may operate through observable factors (e.g. a number of barriers may be common to certain sectors), but also unobservables (i.e. the disturbance term within each model). Hence, to account for the potential correlation in unobservables across different models, these are fitted using seemingly unrelated estimation. The explanatory variables are the same as in the previous analysis.[54]

Lack of internal finance

Model (9) suggests that small, non-exporting manufacturers are more likely to experience lack of internal finance as an obstacle to innovation. There is no clear pattern in the relationship between growth and propensity to innovate.

Lack of credit or private equity

Most of the predictors are not statistically significant in the model explaining the incidence of lack of credit or private equity.

The only statistically significant odds ratios are attached to turnover and employment growth although no clear pattern emerges from these. Of note is a high and statistically significant odds ratio attached associated with the negative turnover growth range of -100%/-70%: this is likely to reflect the fact that businesses with strongly deteriorating fundamentals are more likely to struggle accessing external finance. Other odds ratios attached to negative turnover growth ranges are also higher than 1 but not statistically significant. Most odds ratios for positive turnover growth ranges are lower than 1 (suggesting that growing firms are less likely to experience a lack of credit or private equity),[55] but only one is statistically significant.

There is no clear pattern in the relationship between employment growth and the incidence of lack of credit or private equity as a barrier to innovation. The odds ratios that are significant suggest that SMEs with growing (declining) employment are less (more) likely to experience lack of credit or private equity, but two of the other (i.e. non-statistically significant) coefficients are inconsistent with this pattern (the coeficients on the lowest and highest employment ranges are respectively lower and higher than 1).

[54] The estimation sample includes SMEs from Czechia, Estonia, Greece, Croatia, Hungary, Lithuania, Latvia, Portugal and Romania.

[55] An exception to this pattern is an odds ratio greater than 1 on the indicator of turnover growth of 40%-70% (it is not, however, statistically significant).

Lack of skilled employees

In the model explaining lack of skilled employees, most predictors are not statistically significant. A notable exception is the odds ratio on legal status which is statistically significant and lower than 1. This may be because enterprise groups are conducive to labour pooling (e.g. through secondments).

Difficulties in obtaining grants or subsidies

Small, non-exporting manufacturers are more likely to experience difficulties in obtaining grants or subsidies. These characteristics are similar to those associated with lack internal finance.[56] This is expected as both barriers are related to the funding of innovation.

Lack of collaboration partners

SMEs in the services sector are less likely to attach high importance to a lack collaboration partners.

Uncertain market demand

Small and independent SMEs in the manufacturing sector are more likely to be hindered in their innovation activities by uncertain market demand. On the other hand, businesses that are part of an enterprise group may be vertically linked to a parent, branch or subsidiary, and therefore face lower uncertainty with respect to potential demand for their innovations.

Too much competition

Small SMEs that do not export are more likely to be hindered in their innovation activities by excessive competition in their market. SMEs operating in trade, manufacturing and services are all more likely to face too much competition than businesses operating in industry.

[56] The coefficients on turnover and employment growth show a different pattern, but none are statistically significant.

Table 22 Barriers faced by non-innovators

Odds ratios	(9)	(10)	(11)	(12)	(13)	(14)	(15)
	Lack of internal finance	*Lack of credit or private equity*	*Lack of skilled employees*	*Difficulties in obtaining grants or subsidies*	*Lack of collaboration partners*	*Uncertain market demand*	*Too much competition*
Sector							
Manufacturing (C)	1.485***	1.244	1.138	1.433*	0.712	1.281**	1.763***
	(0.149)	(0.463)	(0.517)	(0.263)	(0.188)	(0.145)	(0.319)
Trade (G)	0.802	1.100	1.453	1.281	0.868	0.858	1.921***
	(0.138)	(0.412)	(0.615)	(0.355)	(0.219)	(0.240)	(0.322)
Services (H-N, Q, R, U)	0.811	0.881	0.517	0.896	0.528***	0.958	1.314*
	(0.124)	(0.316)	(0.247)	(0.129)	(0.059)	(0.245)	(0.190)
Number of employees							
50-249 employees	0.733***	0.757	0.881	0.758**	0.794	0.593***	0.758*
	(0.087)	(0.131)	(0.131)	(0.086)	(0.114)	(0.068)	(0.116)
Administrative status							
Part of a group	1.130	1.020	0.728*	0.764	0.529	0.671**	0.767
	(0.179)	(0.210)	(0.138)	(0.137)	(0.208)	(0.120)	(0.155)
Export behaviour							
Exporter (2012)	0.780***	0.996	0.888	0.826**	0.881	0.876	0.666***
	(0.071)	(0.122)	(0.127)	(0.072)	(0.163)	(0.109)	(0.087)
Turnover growth							
-100%/-70%	0.602	2.178***	0.681	1.090	0.933	0.572	0.962
	(0.256)	(0.584)	(0.589)	(0.331)	(0.686)	(0.231)	(0.293)
-70%/-40%	0.869	1.331	0.908	1.077	0.782	1.149	1.227
	(0.130)	(0.277)	(0.229)	(0.254)	(0.255)	(0.192)	(0.260)
-40%/-10%	1.502***	1.324	1.063	1.101	0.827	0.954	1.083
	(0.192)	(0.235)	(0.095)	(0.173)	(0.134)	(0.178)	(0.185)
10%/40%	0.805*	0.762**	1.038	1.078	0.764***	0.735**	0.904
	(0.091)	(0.102)	(0.102)	(0.202)	(0.076)	(0.097)	(0.127)
40%/70%	0.783	1.091	0.497**	0.868	0.785	0.495***	0.465***
	(0.132)	(0.223)	(0.141)	(0.165)	(0.142)	(0.125)	(0.111)
70%/100%	0.733	0.803	0.711	0.868	0.442	0.483	1.394
	(0.277)	(0.288)	(0.364)	(0.386)	(0.311)	(0.279)	(0.486)
over 100%	0.742	0.945	0.802	0.792	0.791	0.608**	0.806
	(0.181)	(0.171)	(0.153)	(0.157)	(0.399)	(0.151)	(0.158)
Employment growth							
-100%/-70%	1.072	0.881	2.059	0.450	1.572	0.490	1.416
	(0.820)	(0.665)	(2.134)	(0.268)	(1.005)	(0.642)	(0.710)
-70%/-40%	1.571	1.753*	1.124	0.686	1.308	0.790	0.732*
	(0.563)	(0.581)	(0.286)	(0.289)	(0.433)	(0.137)	(0.119)
-40%/-10%	1.282**	1.015	1.147	0.932	1.090	1.199	1.121
	(0.157)	(0.107)	(0.213)	(0.126)	(0.192)	(0.214)	(0.141)
10%/40%	1.042	0.827**	1.244	0.957	0.929	1.025	0.803
	(0.124)	(0.061)	(0.196)	(0.154)	(0.245)	(0.189)	(0.117)
40%/70%	0.763	0.784	1.106	0.926	1.032	0.927	0.880
	(0.203)	(0.281)	(0.224)	(0.240)	(0.410)	(0.398)	(0.251)
70%/100%	0.537***	0.604*	0.765	0.778	1.010	1.047	0.802
	(0.114)	(0.165)	(0.664)	(0.185)	(0.508)	(0.605)	(0.152)
over 100%	1.319	1.215	1.585	0.804	0.588	1.574	0.686
	(0.343)	(0.341)	(0.902)	(0.277)	(0.348)	(0.619)	(0.266)
Country dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	2017	2017	2017	2017	2017	2017	2017
Pseudo R-squared	0.051	0.059	0.032	0.048	0.044	0.050	0.040
Hosmer and Lemeshow (p-value)	0.1906	0.9074	0.8375	0.5867	0.3075	0.1649	0.3471

**p<0.1, **p<0.05, ***p<0.01*

Note: Standard errors in parentheses. Baseline categories are: Industry (NACE Rev. 2 sections B/D-F), 10-49 employees, growth between -10% and 10% (in turnover/the number of employees).

Source: LE Europe analysis of the Community Innovation Survey 2014

7.5.4 Public financial support for innovation

The European Union has set up a number of programmes that offer financial support for the innovation activities of SMEs (e.g. the Horizon 2020 programme). In addition, Member States often have their own schemes in place, ranging from tax incentives for R&D to subsidized loans or grants. The following paragraphs investigate the potential effect of these programmes on innovation behaviour. Four indicators are used:

- The share of turnover from new-to-business innovations;
- The share of turnover from new-to-market innovations;
- R&D intensity, or in-house R&D expenditure divided by turnover;
- Total expenditure on innovation activities, divided by turnover.[57,58]

Identification strategy

The CIS 2014 includes a question that captures whether SMEs have received any public financial support for innovation activities between 2012 and 2014. This can be considered as a 'treatment' which only some SMEs are exposed to. The objective of this analysis is to identify the effect of this treatment on innovation behaviour. There are, however, a number of challenges associated with identification because innovation behaviour and the receipt of public financial support are likely to be related through other channels than the 'treatment effect'.

First, the receipt of public financial support depends on SMEs' decision to apply for a given programme. For instance, innovation-driven businesses may be more likely to seek public financial support than businesses that do not rely as much on innovation. At the same time, the former set of businesses is also more likely to engage more intensively (and successfully) in these activities. Second, the outcome applications for public financial support may depend on the perceived potential of businesses to produce successful innovations which in turn is presumably correlated with their actual propensity to innovate.

To overcome the aforementioned sources of endogeneity, a counterfactual or 'control' group is constructed such that it resembles the 'treated' businessses (i.e. those that have received public financial support for innovation) as closely as possible. This is achieved through a matching process that aims to combine treatment and control businesses that have similar characteristics.

The underlying assumption behind this approach is that, conditional on certain characteristics or variables (referred to as 'the covariates' in the rest of this section), the assignment to treatment (i.e. the receipt of public financial support for innovation activities) is independent of the potential outcomes of treatment and non-treatment. The validity of this assumption, commonly refered to as 'the conditional independence assumption (CIA)', rules out the possibility that any factors other than the covariates affect both treatment assignment and businesses' responsiveness to the treatment (Caliendo and Kopeinig, 2005; Guo and Fraser, 2010; Rosenbaum and Rubin, 1983; Lechner, 1999).

Assuming a set of covariates satisfying this assumption is available, treated units could theoretically be matched to non-treated units with the same characteristics. However, many datasets will not contain untreated observations for each combination of treated characteristics, especially if these span many dimensions. This is referred to as the 'dimensionality curse'. A solution solution to this problem is to match not on exact combinations of covariates but on the estimated probability of treatment, conditional on

[57] This includes in-house and external R&D, the acquisition of machinery, equipment, software, buildings and existing knowledge from other enterprises or organisations, and other activities (e.g. design, training, marketing) (Eurostat, 2014).
[58] There are some instances in which the latter two indicators are greater than 1. This can occur if R&D expenditure or total expenditure on innovation activities is greater than turnover. This concerns only a small number of businesses (indeed, for both indicators, the 99th percentile has a value of 1 or less). In these cases, the values of R&D intensity and the expenditure on innovation activities as a share of turnover are limited to an upper bound of 1. This limits the influence of outliers on results while still retaining these businesses in the dataset.

these variables – this is referred to as the propensity score (Caliendo and Kopeinig, 2005; see also Rosenbaum and Rubin, 1985).[59]

Hence, the identification strategy follows a three-stage procedure. First, the conditional probability of treatment assignment is estimated for each observation. Second, untreated businesses are matched to treated businesses. Finally, the outcomes of the treated and non-treated businesses are compared. This is captured through the average treatment effect on the treated (ATT), which denotes the difference between the average of the outcome variable among the treated units, and the weighted average within the control group.[60]

Propensity score estimation, Matching and Diagnostics

Propensity score estimation

To calculate the propensity score of different SMEs, Probit models are estimated. The dependent variable is an indicator of whether an SME has received public financial support for innovation activities (i.e. the treatment). The covariates include factors which are thought to affect the probability of treatment but are not influenced by it. Most variables in the CIS 2014 dataset are likely to violate the second requirement (i.e. they are probably affected by the the treatment). Therefore, the propensity score is estimated based on a limited set of explanatory variables:

- Country;
- Sector;
- Employment size class;
- Whether a business exported in 2012;
- Whether a business is part of an enterprise group.[61]

Each measure of innovation behaviour is available for a different set of observations. Hence, four sets of propensity scores are estimated, each based on the sub-sample of SMEs for which a given indicator is populated. This is illustrated in Table 23. The estimation of propensity scores is based on unweighted data.

Matching

Based on the propensity scores, 'control' observations that did not receive public financial susupport for innovation activities are matched to businesses that received the treatment. A 'Nearest-neighbour' matching algorithm is used to construct the counterfactual. This approach consists in selecting, for each treated unit, the untreated observations with the closest propensity scores. In the present case, the five untreated businesses with the closest propensity scores are selected (ties are included). Untreated businesses are drawn with replacement.[62] In addition, to ensure that matches are close enough in terms of their propensity scores, a 'caliper' is applied: only controls that have propensity scores within a radius of one fifth of the standard deviation of the propensity score distribution are matched to treated businesses. This helps satisfy the 'overlap' or 'common support' requirement (if every business with a given set of characteristics is either treated or untreated with absolute certainty, a treatment effect is not defined for these businesses – hence, the propensity scores of both treated and control businesses are required to have

[59] If the potential outcomes are independent of treatment assignment given a combination of covariates, then they are independent of assignment given the propensity score (Rosenbaum and Rubin, 1983).
[60] The wieghts are based on the frequency with which a given untreated observation is used as a match for a treated business (see below for details on the matching process).
[61] Turnover or employment growth are not included in the model as it is unclear whether growth is determined by the treatment and such an assumption could not be assessed through any robustness checks as was the case in the previous analysis (this was done by selecting ongoing innovation as the dependent variable, which presumably did not affect growth).
[62] The frequency with which business is matched is used to determine the wieght of each control observation in the calculation of the ATT.

a common support).[63] The matched samples for each innovation behaviour indicator are shown in Table 23.

Table 23 Sample sizes before and after matching

	R&D intensity		*All innovation expenditure divided by turnover*		*Share of turnover from new-to-business product innovations*		*Share of turnover from new-to-market product innovations*	
	Controls	***Treated***	***Controls***	***Treated***	***Controls***	***Treated***	***Controls***	***Treated***
Before matching	5076	2497	7384	3404	5491	2748	5552	2783
After matching	4945	2497	7218	3404	5373	2748	5408	2783

Source: LE Europe analysis of the Community Innovation Survey 2014

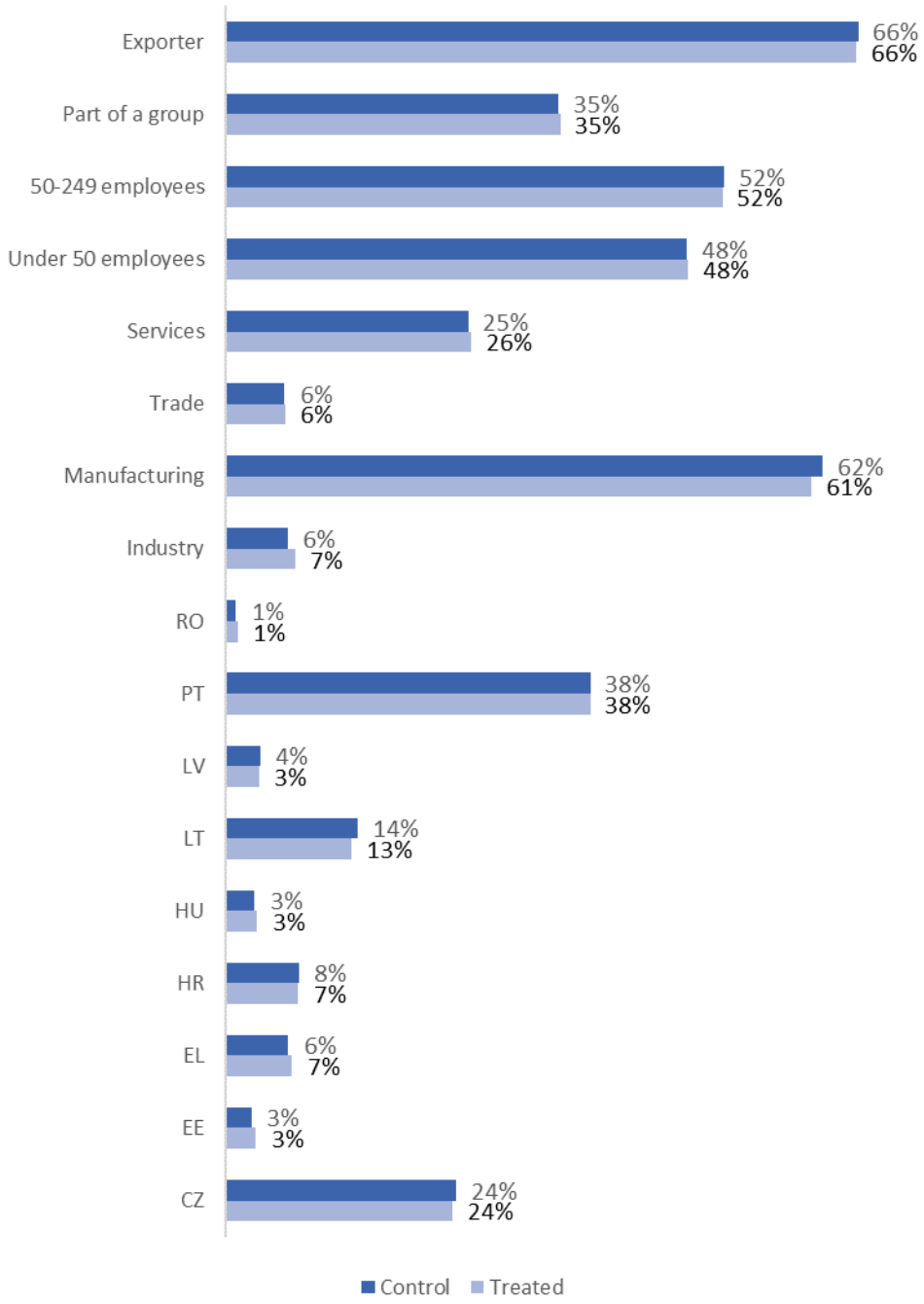
Diagnostics

If the treatment and control groups were correctly matched, the covariates should be poor predictors of treatment assignment after matching. This is commonly assessed by checking whether covariates are 'balanced' across both groups. Two approaches were adopted.

First, the frequency of each indicator was compared across groups, and statistical tests were conducted to assess whether these frequencies differed significantly. As shown in Figure 26, Figure 27, Figure 28, Figure 29, all covariates are well balanced across the treatment and control groups for each of the matched samples. Indeed, the frequency of each indicator is almost identical in each sub-sample and there were no statistically significant differences.

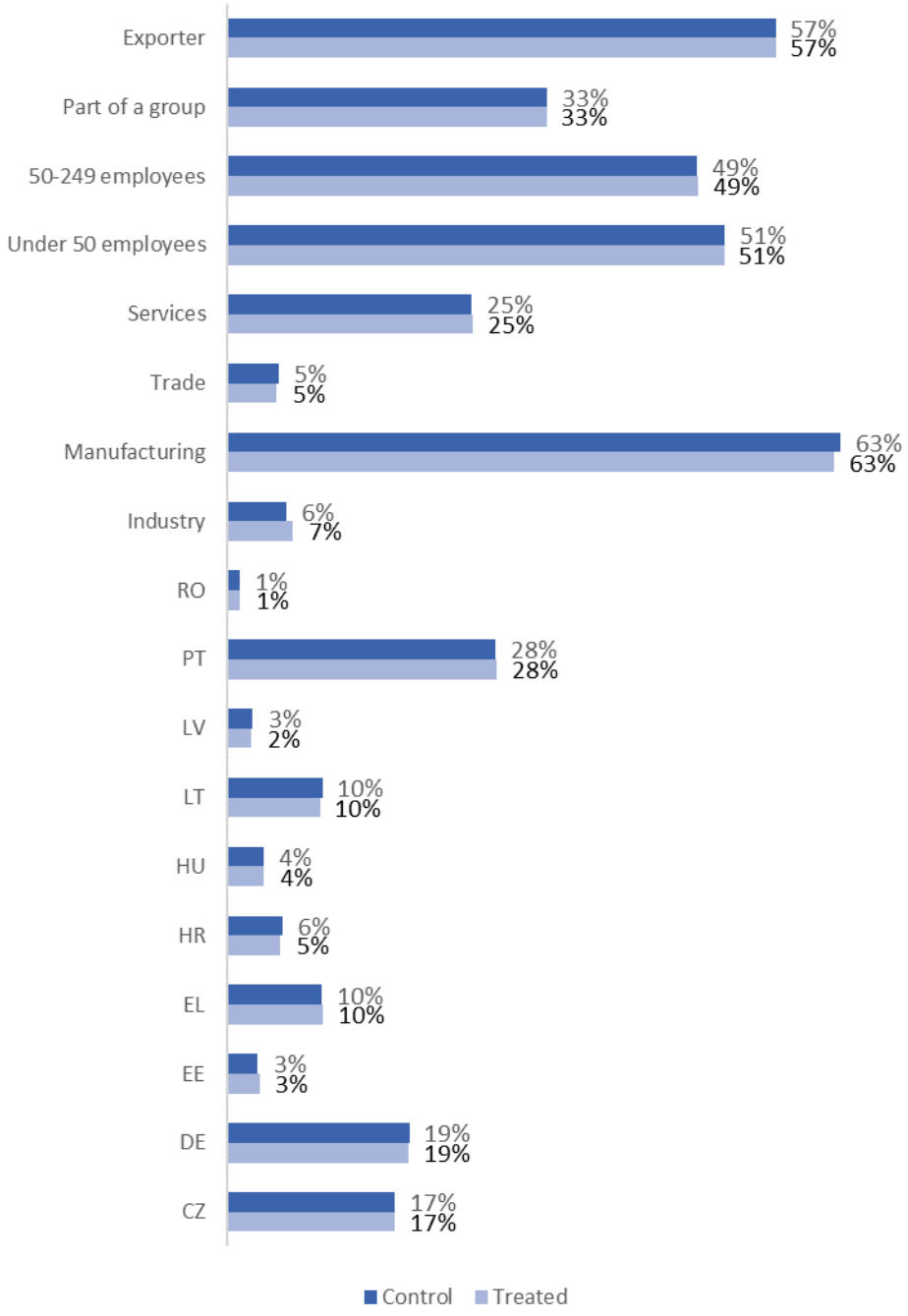
[63] In addition, propensity scores are restricted to a common interval (i.e. a common minimum and maximum).

Figure 26 Frequency of covariates – by treatment status (R&D intensity)



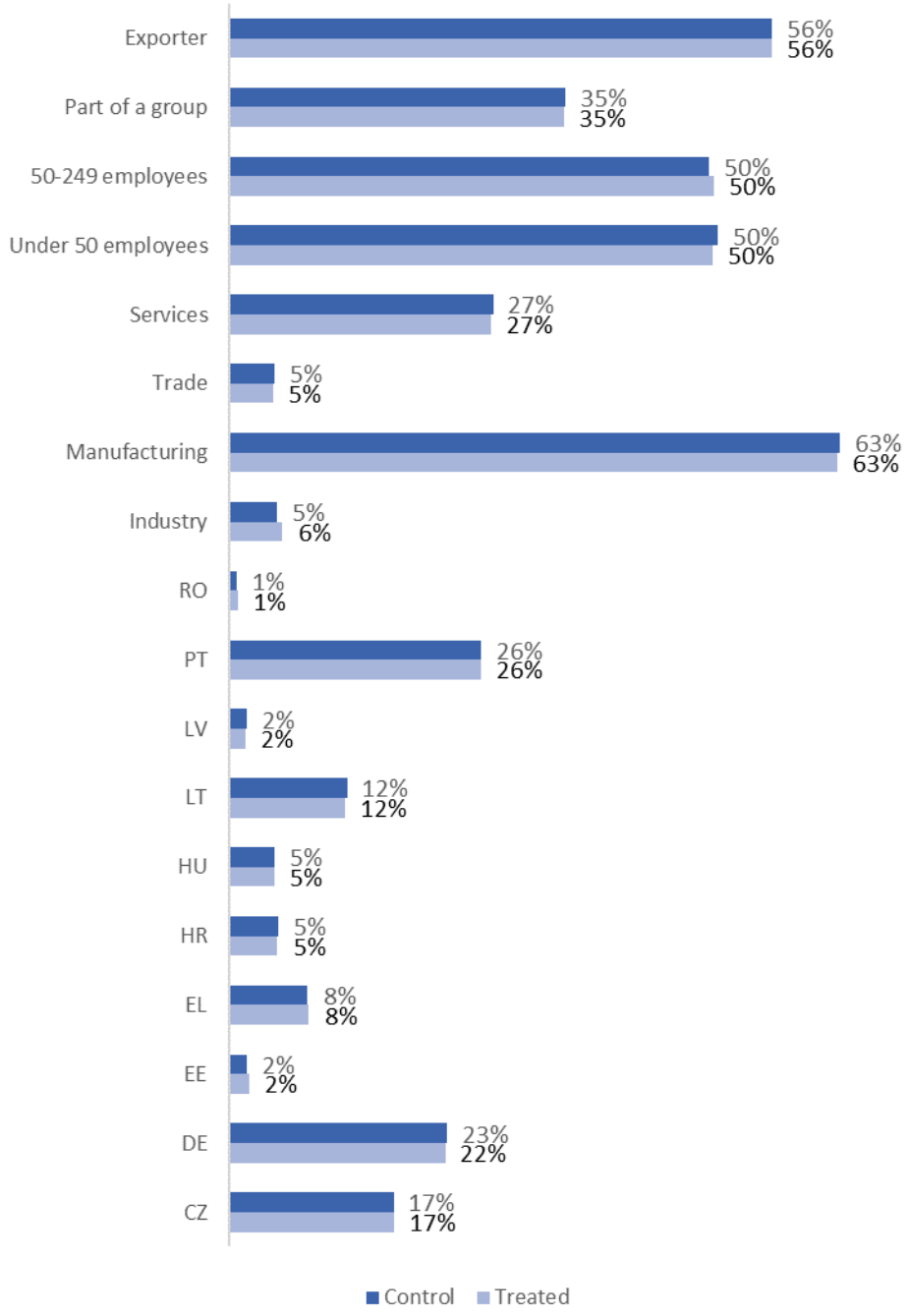
Note: Number of observations: 7442, of which 2497 were part of the treatment group and 4945 were part of the control group.
Source: LE Europe analysis of the Community Innovation Survey 2014

Figure 27 Frequency of covariates – by treatment status (Innovation expenditure divided by turnover)



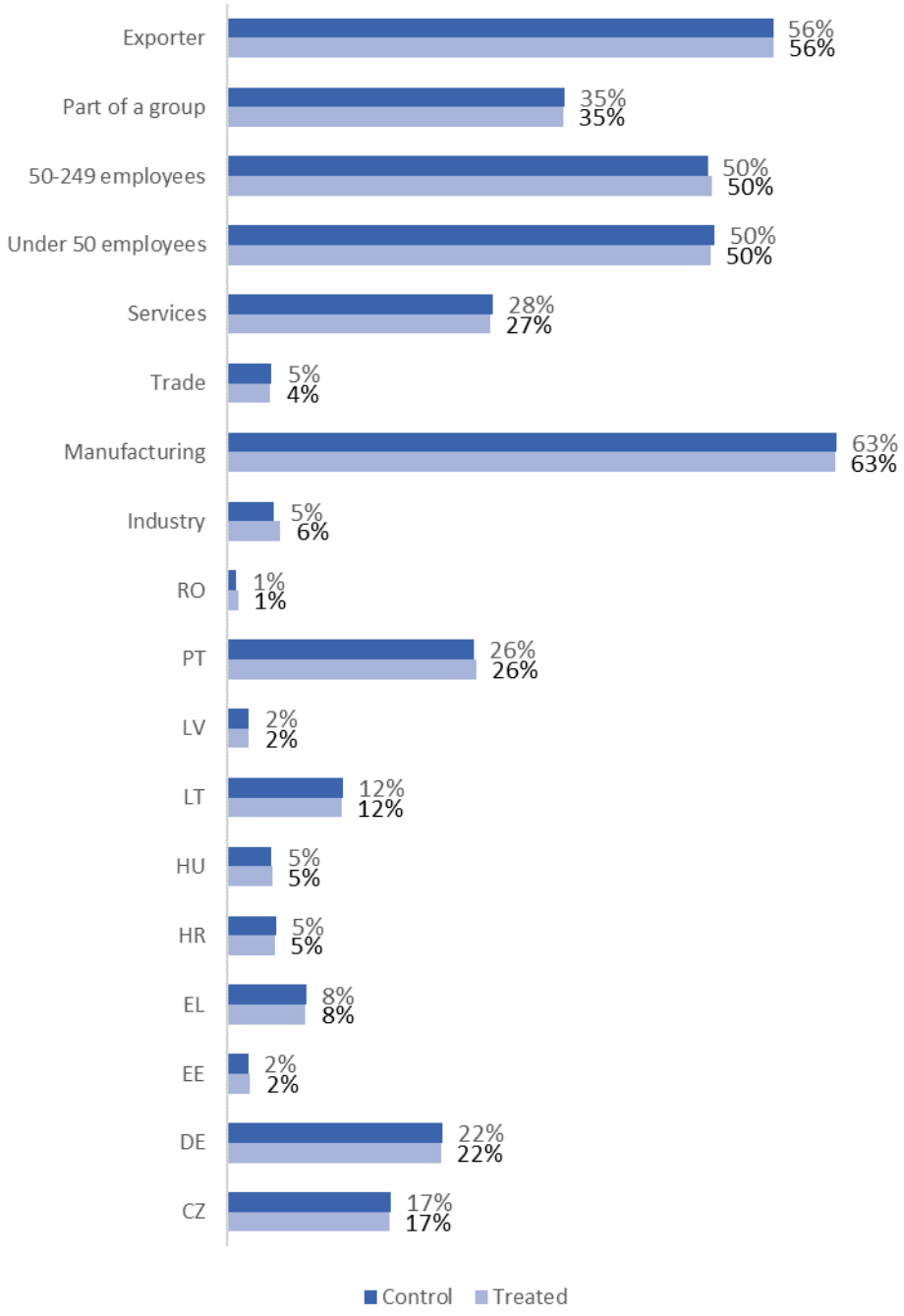
Note: Number of observations: 10622, of which 3404 were part of the treatment group and 7218 were part of the control group.
Source: LE Europe analysis of the Community Innovation Survey 2014

Figure 28 Frequency of covariates – by treatment status (share of turnover from new-to-business product innovations)



Note: Number of observations: 8121, of which 2748 were part of the treatment group and 5373 were part of the control group.
Source: LE Europe analysis of the Community Innovation Survey 2014

Figure 29 Frequency of covariates – by treatment status (share of turnover from new-to-market product innovations)



Note: Number of observations: 8191, of which 2783 were part of the treatment group and 5408 were part of the control group.
Source: LE Europe analysis of the Community Innovation Survey 2014

Second, a Probit regression of treatment status on the covariates was fitted on the matched sample. A likelihood-ratio test was conducted to assess the joint significance of the covariates. The p-value from this test on each of the matched samples is reported in Table 24. For comparison, these are also reported for the Probit model that generated the propensity scores which were subsequently used in the matching process (i.e. this model was fit on the unmatched sample). It can be seen that, while before the matching, the covariates were jointly significant, this is no longer the case after matching.

Table 24 Pseudo-R-squared and likelihood-ratio test p-values for the joint significance of covariates in a Probit model predicting treatment status

	Before matching	After matching	Before matching	After matching
	Pseudo-R-squared		*Likelihood-ratio test p-value*	
R&D intensity	0.042	0.001	0.000	0.996
All innovation expenditure divided by turnover	0.035	0.000	0.000	1.000
Share of turnover from new-to-business product innovations	0.037	0.000	0.000	1.000
Share of turnover from new-to-market product innovations	0.037	0.000	0.000	1.000

Source: LE Europe analysis of the Community Innovation Survey 2014

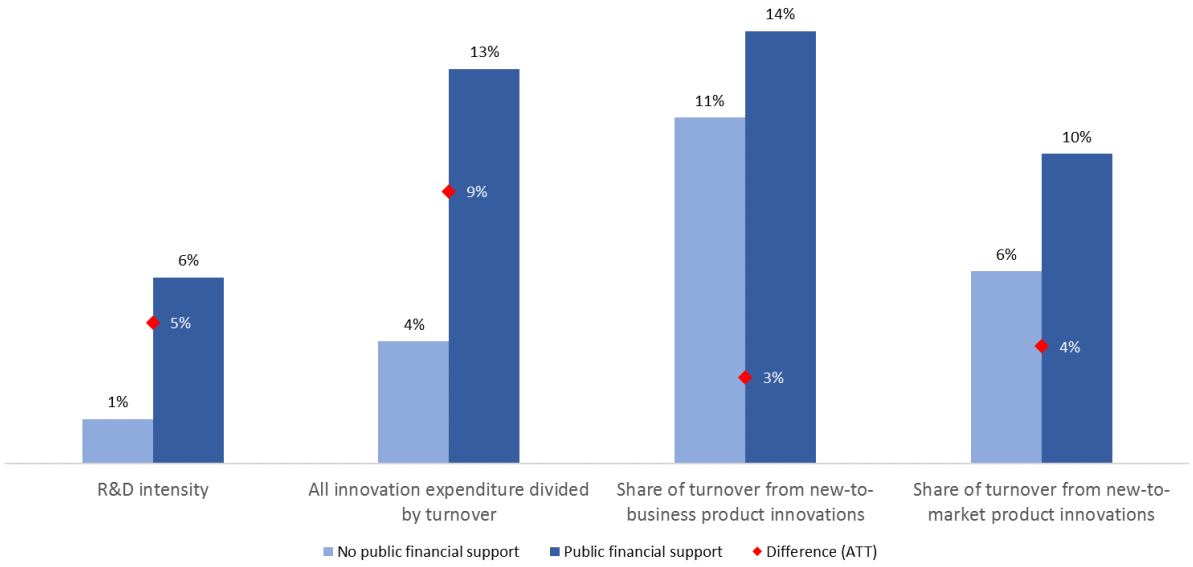
Although the treatment and control groups are balanced with respect to all covariates, it should be noted that these do not do well in predicting treatment. Indeed, in all four models, the pseudo-R-squared is under 0.05. This suggests that there other potentially important factors explaining the treatment which are unaccounted for by the covariates. If these factors are also correlated with any of the outcomes, the CIA would be violated. Given that most other variables in the dataset are likely to be influenced by the treatment, there are limited options to improve the model for estimating the propensity score. To account for additional determinants of public financial support for innovation, an alternative specification includes an indicator for whether SMEs have permanent R&D staff in-house. This follows the logic of Czarnitzki et al. (2006), which use a similar variable to proxy SMEs' level of engagement in R&D. The treatment effects based on this model (presented further below as a robustness check), however, are not directly comparable because they are run on a sub-sample of businesses that have conducted in-house R&D between 2012 and 2014.

Results

Figure 30 suggests that public financial support has a positive impact on 'innovation expenditure' (i.e. 'innovation inputs'), as illustrated by a positive and statistically significant ATT on R&D intensity and total expenditure on innovation activities as a share of turnover. Public financial support for innovation activities is also estimated to have a positive impact on the share of turnover from the sale of innovative products (i.e. an 'innovation output').[64]

[64] The ATT was estimated using the stata command *psmatch2*. In order to calculate standard errors that account for the fact that the propensity scores were estimated (see Abadie and Imbens, 2016), another command – *teffects psmatch* – was employed. Given that both commands treat observations that do not satisfy the common support condition differently, both estimation sets were marginally different (both with respect to the propensity scores and the ATT). However, the effect of this is most likely very small: indeed, that the estimated ATT are very close.

Figure 30 Effect of public financial support for innovation activities on innovation behaviour indicators (average)



Note: country coverage: CZ, EE, EL, HR, HU, LT, LV, PT, RO (R&D intensity). CZ, DE, EE, EL, HR, HU, LT, LV, PT, RO (all other models). All coefficients are statistically significant at the 95% level (at least).

Source: LE Europe analysis of the Community Innovation Survey 2014.

Robustness

To further explore the link between public financial support for innovation activities and innovation behaviour, and to check the robustness of previous results, an alternative specification is used to estimate the propensity scores. As mentioned above, an indicator for whether SMEs had permanent staff for R&D in-house is added to the model in the first stage.

This is firstly intended to improve prediction of the treatment. In addition, given that this new variable is only populated for businesses that have conducted R&D between 2012 and 2014, its inclusion implicitly conditions on having conducted R&D. Hence, results will shed light on the impact of public financial support for innovation activities on the *intensive* margin of innovation behaviour (i.e. the impact on businesses that already conduct innovation activity – in this case, R&D). In contrast, the estimates presented above included both the impact on the intensive margin and the *extensive* margin (i.e. whether public financial support can help kick-start innovation activities or the sale of innovative products).

As shown in Table 25, including an indicator for whether SMEs have permanent R&D staff in-house improves the prediction of treatment.

With respect to balancing, the covariates have similar frequencies across both groups and none of the differences are statistically significant (for concision, these are not reported). However, except in the model explaining R&D intensity, likelihood ratio tests still reject the null hypothesis after matching. This indicates that the covariates are not as well balanced as in the previous analysis. Therefore, the results from these models should be interpreted with caution.

Table 25 Pseudo-R-squared and likelihood-ratio test p-values for the joint significance of covariates in a Probit model predicting treatment status (businesses undetrtaking R&D)

	Before matching	After matching	Before matching	After matching
	Pseudo-R-squared		Likelihood-ratio test p-value	
R&D intensity	0.061	0.002	0.000	0.771
All innovation expenditure divided by turnover	0.162	0.004	0.000	0.052
Share of turnover from new-to-business product innovations	0.171	0.006	0.000	0.005
Share of turnover from new-to-market product innovations	0.167	0.006	0.000	0.006

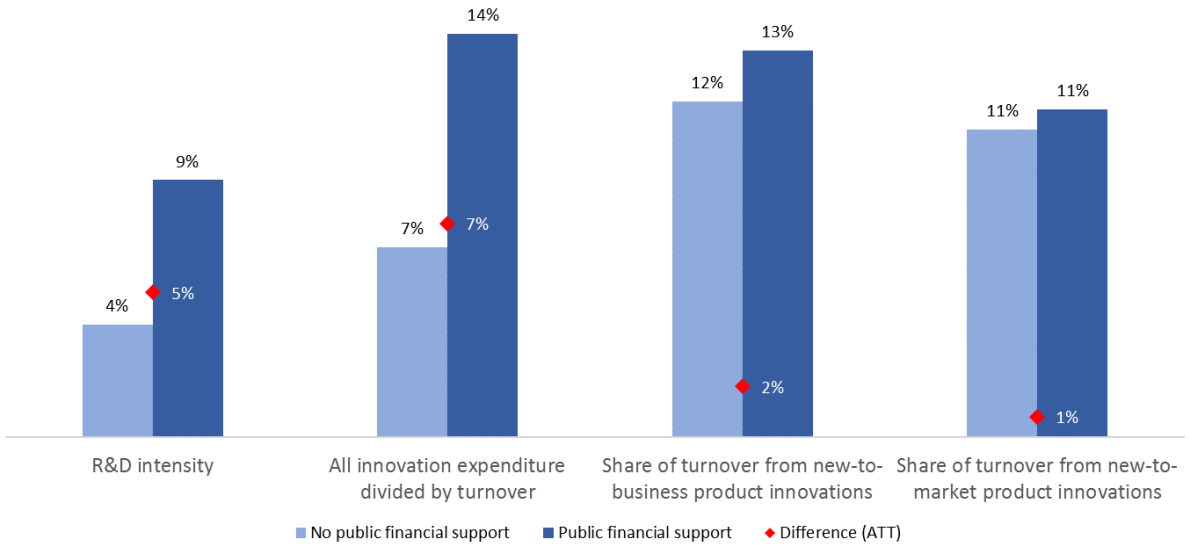
Source: LE Europe analysis of the Community Innovation Survey 2014

In all cases, the results suggest that public support for innovation activities have a positive impact on innovation behaviour, although the estimated ATT on the share of turnover from new-to-market product innovations is not statistically significant.

Compared to the results above, the ATTs are lower. This may be an indication that the previous results were not devoid of bias (indeed, as explained above, the Probit model for estimating the propensity scores did not fit the data as well as the current models, which suggests that the matching may not have eliminated the effect of unobserved factors that may affect both treatment assignment and potential outcomes).

On the other hand, the model explaining R&D intensity both fares better with respect to the balancing of covariates (indeed, the likelihood-ratio test fails to reject the null hypothesis) and yields an ATT that is very close to that from the baseline analysis. Hence, it is possible that the other three models presented in Figure 31 are biased because they are not as well balanced with respect to the covariates as the models from Figure 30.

Figure 31 Effect of public financial support for innovation activities on innovation behaviour indicators – conditional on conducting in-house R&D (average)



Note: country coverage: CZ, EE, EL, HR, HU, LT, LV, PT, RO (R&D intensity). CZ, DE, EE, EL, HR, HU, LT, LV, PT, RO (all other models). All of the ATT are statistically significant at the 95% level (at least), except for that on the share of turnover from new-to-market innovations.
Source: LE Europe analysis of the Community Innovation Survey 2014

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ANNEX 1: SECTORS WHERE INNOVATION IS A CORE ACTIVITY

Sector code	Sector
B	Mining and quarrying
C	Manufacturing
D	Electricity, gas, steam and air conditioning supply
E	Water supply; sewerage, waste management and remediation activities
G46	Wholesale trade, except of motor vehicles and motorcycles
H	Transportation and storage
J	Information and communication
K	Financial and insurance activities
M71	Architectural and engineering activities; technical testing and analysis
M72	Scientific research and development
M73	Advertising and market research

ANNEX 2: INNOVATION RATE AMONG SMEs AND LARGE ENTERPRISES 2014-2016

	Large enterprises			SMEs				
	Organisation and marketing innovative enterprises only	Product and/or process innovative enterprises only	Product and/or process and organisation and/or marketing innovative enterprises	Organisation and marketing innovative enterprises only	Product and/or process innovative enterprises only	Product and/or process and organisation and/or marketing innovative enterprises	**Total innovative large enterprises**	**Total innovative SMEs**
AT	8.4	7.4	70.1	14.4	10.4	36.0	85.8	60.8
BE	2.8	21.1	65.1	6.1	22.1	39.0	89.0	67.2
BG	31.3	19.9	30.7	6.5	9.5	9.2	81.9	25.2
CY	5.0	7.5	50.0	7.3	8.2	20.3	62.5	35.8
CZ	7.0	20.1	50.3	9.2	13.3	22.2	77.4	44.6
DE	11.6	17.6	61.8	13.8	16.8	31.8	91.0	62.3
DK	7.8	9.9	53.0	12.2	8.4	27.0	70.7	47.6
EE	3.8	27.4	54.7	3.3	26.2	17.1	85.8	46.6
EL	6.0	16.1	61.9	10.7	10.9	35.6	83.9	57.2
ES	9.7	17.4	47.8	14.3	8.6	12.8	74.9	35.8
EU-28	9.6	17.3	50.5	11.1	13.8	24.5	77.4	49.5
FI	4.0	15.1	65.6	6.6	19.1	38.2	84.7	63.9
FR	9.6	13.7	58.5	14.7	11.2	30.5	81.9	56.4
HR	12.2	8.4	53.2	14.5	9.3	23.1	73.8	46.9
HU	9.6	11.5	35.3	7.7	9.4	10.8	56.4	27.8
IE	9.8	9.8	61.8	14.7	7.7	33.9	81.4	56.3
IT	5.1	15.4	63.7	9.8	14.2	29.1	84.3	53.1
LT	8.1	20.3	63.8	9.8	15.8	23.6	92.3	49.2
LU	16.1	13.8	51.7	19.4	10.9	32.6	81.6	62.9
LV	5.8	10.2	51.1	9.0	7.8	12.4	67.2	29.2
MT	0.0	5.7	51.4	7.3	7.1	18.5	57.1	33.0
NL	7.6	26.5	44.2	7.4	27.3	24.2	78.3	58.9
PL	5.4	21.8	34.4	4.2	9.2	6.9	61.6	20.3
PT	2.7	18.4	63.2	8.5	19.0	38.9	84.3	66.4
RO	5.7	3.7	8.5	4.7	2.4	2.6	17.9	9.8
SE	9.6	19.1	50.6	11.7	17.1	24.7	79.3	53.4
SI	5.3	17.1	60.0	8.7	11.1	18.3	82.4	38.1
SK	7.5	17.4	35.0	7.5	9.0	12.5	59.9	29.0
UK	15.5	24.0	32.5	14.2	18.0	26.0	72.0	58.2

Notes: As a percentage of total enterprises in each size class identified as innovators in the 2016 CIS. Data refer to the three-year reference period 2014-2016 and include ongoing or abandoned innovation activities. The industry coverage includes all businesses in which innovation is a core activity. This sector encompasses the following NACE industries: B, C, D, E, G46, H, J, K and M71-72-73. Only enterprises with 10 or more employees are covered.
Source: Eurostat, 2016 CIS

ANNEX 3: INNOVATION RATE AMONG SMEs AND LARGE ENTERPRISES IN THE SERVICES SECTOR

	Large enterprises			SMEs				
	Organisation and marketing innovative enterprises only	Product and/or process innovative enterprises only	Product and/or process and organisation and/or marketing innovative enterprises	Organisation and marketing innovative enterprises only	Product and/or process innovative enterprises only	Product and/or process and organisation and/or marketing innovative enterprises	**Total innovative large enterprises**	**Total innovative SMEs**
AT	16.4	4.1	53.1	16.8	8.6	35.4	73.6	60.7
BE	5.6	16.3	60.2	6.4	21.0	36.4	82.1	63.8
BG	37.5	15.0	25.0	7.4	5.2	8.2	77.5	20.8
CY	0.0	6.7	46.7	8.4	6.9	19.9	53.3	35.2
CZ	12.1	13.8	46.5	10.4	9.1	20.7	72.3	40.2
DE	14.1	17.6	57.2	15.0	12.5	30.3	88.9	57.8
DK	10.6	7.6	46.5	13.4	7.9	26.4	64.6	47.6
EE	5.3	26.3	57.9	3.8	20.4	15.4	89.5	39.6
EL	7.3	11.0	60.6	10.4	10.8	34.9	78.9	56.1
ES	13.7	12.9	38.8	17.0	6.5	11.2	65.4	34.6
EU	12.7	14.4	45.7	12.8	11.4	23.8	72.9	48.0
FI	6.2	21.6	47.5	7.4	16.7	35.9	75.3	60.0
FR	13.2	11.3	52.9	16.6	9.1	29.5	77.5	55.2
HR	14.0	5.4	63.4	16.0	7.4	23.7	82.8	47.2
HU	13.2	8.4	40.1	8.7	8.3	11.4	61.7	28.3
IE	12.9	6.1	51.5	16.1	6.3	31.4	70.5	53.8
IT	7.8	10.4	55.0	13.3	8.4	25.9	73.2	47.6
LT	12.1	15.4	64.8	9.9	14.6	24.5	92.3	49.0
LV	5.5	5.5	46.6	10.0	6.3	11.3	57.5	27.7
MT	0.0	0.0	50.0	8.7	4.9	18.5	50.0	32.1
NL	9.5	26.2	39.8	7.9	25.6	23.4	75.5	57.0
PL	7.2	16.3	27.6	3.9	7.8	5.8	51.1	17.6
PT	3.4	12.0	60.6	11.5	16.7	42.9	76.0	71.2
RO	7.1	4.9	7.6	5.1	2.4	2.3	19.6	9.7
SE	13.0	13.7	46.2	13.0	14.4	25.4	72.9	52.7
SK	12.4	8.0	35.4	8.8	7.0	11.7	55.8	27.5
UK	17.7	18.0	30.9	14.7	16.3	27.4	66.6	58.4

Notes: As a percentage of total enterprises in each size class identified as innovators in the 2016 CIS. Data refer to the three-year reference period 2014-2016 and include ongoing or abandoned innovation activities. The industry coverage includes all businesses in which innovation is a core activity in the services sector. This sector encompasses the following NACE Rev. 2 industries: G46, H, J, K, M71, M72, and M73. Only enterprises with 10 or more employees are covered. The EU data cover the following Member States: AT, BE, BG, CY, CZ, DE, DK, EE, EL, ES, FI, FR, HR, HU, IE, IT, LT, LV, MT, NL, PL, PT, RO, SE, SK and UK.

Source: Eurostat, 2016 CIS

ANNEX 4: INNOVATION RATE AMONG SMEs AND LARGE ENTERPRISES IN THE MANUFACTURING SECTOR

	Large enterprises			SMEs				
	Organisation and marketing innovative enterprises only	Product and/or process innovative enterprises only	Product and/or process and organisation and/or marketing innovative enterprises	Organisation and marketing innovative enterprises only	Product and/or process innovative enterprises only	Product and/or process and organisation and/or marketing innovative enterprises	**Total innovative large enterprises**	**Total innovative SMEs**
AT	3.2	8.5	80.8	10.3	13.6	38.5	92.5	62.4
BE		24.6	69.4	5.7	23.7	43.9	93.9	73.3
BG	23.6	23.9	39.9	5.5	13.8	10.4	87.3	29.7
CY	22.2	11.1	55.6	5.3	11.2	21.3	88.9	37.9
CZ	5.2	22.6	52.6	8.1	17.2	24.3	80.4	49.5
DE	9.8	17.9	65.3	11.7	21.9	34.9	93.0	68.5
DK	3.8	12.8	61.7	10.4	9.2	28.3	78.2	47.9
EE	3.3	30.0	50.0	2.6	31.3	19.2	83.3	53.1
EL	5.3	22.1	64.2	11.5	10.2	37.0	91.6	58.8
ES	4.7	22.4	59.3	11.2	11.3	15.2	86.4	37.7
EU	7.1	19.6	54.9	9.1	16.6	25.8	81.5	51.5
FI	2.4	9.0	82.0	5.2	22.5	42.3	93.4	70.0
FR	5.0	16.1	66.2	12.2	14.1	32.2	87.3	58.6
HR	10.1	9.5	48.6	13.4	9.9	23.5	68.2	46.9
HU	8.2	13.5	34.1	6.6	10.6	10.4	55.8	27.6
IE	7.9	14.3	70.0	11.4	11.2	40.4	92.1	62.9
IT	1.9	19.6	72.8	7.5	17.9	31.7	94.3	57.2
LT	6.6	22.6	62.8	9.9	16.7	23.2	92.0	49.7
LV	7.5	17.0	50.9	7.8	10.0	14.7	75.5	32.5
NL	5.5	26.7	51.1	5.9	31.4	26.4	83.3	63.7
PL	4.5	24.3	38.0	4.6	10.0	8.0	62.3	22.5
PT	1.8	23.4	64.2	6.4	20.4	36.6	89.4	63.4
RO	5.5	3.6	9.6	4.6	2.7	3.3	18.8	10.6
SK	5.1	21.5	35.3	6.7	11.1	13.6	61.8	31.4
UK	12.8	32.9	34.4	12.8	22.4	24.0	80.1	59.2

Notes: As a percentage of total enterprises in each size class identified as innovators in the 2016 CIS. Data refer to the three-year reference period 2014-2016 and include ongoing or abandoned innovation activities. The industry coverage includes all businesses in which innovation is a core activity in the manufacturing sector. This sector encompasses the following NACE Rev. 2 industry: C. Only enterprises with 10 or more employees are covered. The EU data cover the following Member States: AT, BG, CY, CZ, DE, DK, EE, EL, ES, FI, FR, HR, HU, IE, IT, LT, LV, NL, PL, PT, RO, SK and UK.
Source: Eurostat, 2016 CIS

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