

# Patenting in 4IR Technologies and Firm Performance

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## • Obiettivi

The last decade has witnessed increasing attention to the Fourth Industrial Revolution – from now on, 4IR (Schwab, 2017). Academic scholars, practitioners (managers, entrepreneurs and technologists) and policy makers have sparked a debate on the potential role of 4IR in the technological development and transformation of production processes (Brynjolfsson and McAfee, 2014; Deloitte, 2018; Santos et al., 2017). The 4IR promises to revolutionise several aspects of social and economic life. Manufacturing is a case in point: digitalised information on customer needs, processed through analytics and social media, together with real-time, flexible manufacturing systems, allows mass customisation to be achieved. Apart from production systems, 4IR technologies and applications open up unprecedented opportunities to drastically change already existing industries – for instance, transportation (through drones and driverless cars) and healthcare (personalised medication) – and create new ones (Rüßmann et al., 2015; WEF, 2016a).

The current academic literature on 4IR has mainly focused on: (i) the potential technological disruption of 4IR (Benassi et al., 2020; EPO, 2020; Li et al., 2021; Martinelli et al., 2021) and the future consequences on employment (Frey and Osborne, 2017; Graetz and Michaels, 2018); (ii) the analysis of specific 4IR technologies, such as artificial intelligence systems, robots and the like (Cockburn et al., 2018; Dernis et al., 2019; Kromann et al., 2020). However, despite this widespread interest, evidence on the implications of 4IR for companies is scant. We consider this lack of evidence particularly unfortunate, as a better understanding of the implications of the development of these technologies for firms' performance could significantly inform the current debate on firm-level competitiveness, performance and strategy (Raj and Seamans, 2018).

In this paper, we analyse the extent to which the accumulation of knowledge in the development of 4IR technologies over time is associated with firm performance, as measured by labour productivity, total factor productivity and accounting profitability. We further explore whether such a relationship is affected by the firm's history in the development of 4IR technologies, as measured by the firm's experience and continuity in 4IR technological development. Finally, we assess whether the relationship between 4IR

technology development and firm performance is different for specific technological areas within the broader 4IR remit.

### • **Metodologia**

For our empirical analysis, we use a panel data set obtained from ORBIS-IP, including the population of large firms (i.e., with more than 250 employees) that have filed at least one patent in the 4IR domain at the European Patent Office (EPO) in the 2009–2014 period, and we reconstruct the firm-specific history of patent filings in the 4IR technological classes from 1985 onwards. We identify 4IR patents by applying a novel two-step procedure proposed by the EPO, which is based on a combination of Cooperative Patent Classification (CPC) codes and a full-text patent search of multiple keywords identifying 4IR technologies (EPO, 2020). We analysed six major technological groups comprising 4IR technologies: Cyber-Physical Systems (CPS); Industrial Internet of Things (IIoT); Artificial Intelligence (AI), cognitive computing and big data analytics; cloud computing/manufacturing; Augmented Reality (AR); wireless technology. We focused on large firms because they account for almost the totality of 4IR patent applications. From our computations on the ORBIS-IP data set, it emerges that large firms account for over 98% of all 4IR patent applications to the EPO since 1985. The possibility to go back in time by as much as 30 years in the construction of 4IR (and non-4IR) patent stocks allows us to capture the accumulated experience on 4IR technologies developed by companies since the 4IR inception. As is standard practice in the literature, we use patent filings as a proxy for a firm's innovation capabilities (e.g., see Artz et al., 2010; Grinza and Quatraro, 2019; Sears and Hoetker 2014). Although they may be an imprecise proxy of technological and innovation activities at the firm level (e.g., because the propensity to patent differs across firms and industries; not all inventions are patented; patents can be filed for strategic reasons), patents still represent the most commonly and widely accepted way of measuring a firm's technological capabilities, and are generally considered valid and robust indicators of knowledge creation and innovation (Trajtenberg, 1987).

### • **Risultati**

Our main results, obtained after controlling for a wide array of patent- and firm-level characteristics and firm fixed unobserved heterogeneity, show a positive and significant relationship between the stock of 4IR patents and productivity (both labour productivity and total factor productivity), but no correlation with profitability. The positive relationship with productivity is mainly driven by companies that are characterised by higher experience and continuity in 4IR technology development and that have started earlier to develop 4IR inventions (i.e., in the 1985–1994 decade). Furthermore, when we disentangle the specific subsets of 4IR technologies, we find that the positive relationship is stronger for 4IR-related wireless technology and for AI, cognitive computing and big data analytics.

- **Implicazioni**

Our evidence thus suggests that the development of 4IR technologies has its major impact on the firm's production process, while the positive effects in terms of profitability remain still to be seen. Moreover, accumulated experience in the development of 4IR technological capabilities appears to be relevant for firm productivity, which suggests that learning in the 4IR domain heavily depends on the ability to take stock of the development of 4IR technologies.

Our paper is but a preliminary exploration of the strategic, technological and competitive implications of 4IR technology development and sheds light on these issues from a company perspective.