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# Innovation over the industry life-cycle. Does ownership matter?

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ABSTRACT

This paper considers the impact of firm ownership on innovation over the industry life-cycle. By analyzing a sample of 9602 European manufacturing firms, we first confirm established evidence that firms focus on product-oriented innovation during the growth stage of the industry life-cycle, and on process-oriented innovation during maturity. When firm ownership is taken into account, we find that this pattern is strongly reversed by the shifts from growth to maturity, but only for family firms, as these firms are significantly more prone to introduce risky product innovations during maturity. Controls for firm size, financial resources and other firm-specific variables, together with an explicit consideration of managerial ability, help in rejecting the hypothesis that family firms rely on product innovation for the inferior ability to manage process and organizational innovation. In addition, we find that the adoption of risky product innovation during maturity is mainly associated with family ownership, not management. By contrast, family management favors risk-avoiding behavior, except in the case of experienced family CEOs.

## 1. Introduction

There is a strong link between technological innovation and firm performance. Innovation creates new knowledge and allows firms to develop new products, enhance productivity, remain competitive, and ensure long-term survival (Tellis et al., 2009; Schmid et al., 2014; Minetti et al., 2015).

The current theory has highlighted differences in the innovative behavior of firms across phases of the industry life-cycle (Klepper, 1996; 1997). In the initial stage, an industry may be pioneered by a few firms but, as the industry gains legitimacy, the number of firms rises thanks to differentiation and new product introductions. During growth, unstable consumer preferences and increasing demand further promote product innovation and support entry. With the onset of maturity, products become more standardized and the competitive scenario is characterized by efficiency-based competition. Product innovation leaves room for process innovation (Henderson and Clark, 1990; O'Reilly and Tushman, 1997; McGahan and Silverman, 2001) and firms concentrate on managerial practices (Bloom and Van Reenen, 2010). Then, when the industry enters the shakeout stage, the rate of firm failure increases sharply and industry consolidates around fewer players. At this stage, the risk of exiting the market becomes substantial, thus making firms concerned about survival and long term presence in the industry.

This situation can be particularly alarming for those owners who want to pass the firms to heirs, like family firms. If firm owners value control over company assets, they may find it optimal to accept some additional risk in order to increase their chances to survive the shakeout. More generally, family owners – as well as other owners managing for the long term – may be willing to accept risky product innovation when the probability to exit the industry becomes substantial. The paper investigates this question by studying if firm innovation activity along the industry life-cycle depends on the type of the company owner, thus making ownership a crucial variable to understand the company innovation profile.

Family firms are ideal candidates for research into how the industry life-cycle affects innovation decisions. Because of their long term orientation, these owners typically invest a significant amount of their wealth in the company and want to transfer the firms down the generations. They value control over assets even more than performance (Miller and Le Breton-Miller, 2005; Burkart et al., 2003; Bertrand and Schoar, 2006; Gomez-Mejia et al., 2007; Bandiera et al., 2015), and this makes them highly sensitive to business risk conditions prevailing in the industry. Recent literature shows that while in normal times the business risk may negatively influence family firm innovation decisions (Schmid et al., 2014; Minetti et al., 2015), family firms may see risky innovation as necessary when firm survival is at risk. Chrisman and Patel (2012) and Patel and Chrisman (2014) explore a similar argument, that is family businesses invest more in risky R&D expenditure when performance falls below aspirations, or the firm underperforms in

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comparison to previous performance. However, they use the past performance of firms as a reference point and main motivation behind the acceptance of the R&D risk. By contrast, here we focus on the exogenous influence of the industry life cycle on the innovation decision of firm owners, regardless of the firms' previous poor or good performance, or other firm-level incentive mechanisms. We argue that the shift in the industry life-cycle from growth to maturity selectively affects the innovation incentives of different types of owners, thus providing an additional mechanism to explain the innovation profile of incumbents. Thus, our approach introduces an industry-level explanation to firm innovation behavior which is based on the differential reaction of owners to common changes in the industry life-cycle.

Anecdotal evidence provides support to this intuition. The consolidation of the household appliances industry at the end of the '70s pushed Indesit Company, a major Italian producer of household appliances owned by the Merloni family, to start an ambitious and risky research program on domestic automation (domotics). This program ended up with the release of a line of domotic products completely new to the industry and was followed, in the early '90s, by the introduction of the most innovative washing machine in the market, the fully-electronic, fuzzy logic-governed Margherita Dialogic. Similarly, the consolidation process in the food industry occurred in Italy in the late '70s drove Barilla, a leading Italian company owned by the Barilla family, to give full support to the launch of the Mulino Bianco initiative, that allowed the company to start the diversification process from the pasta industry into the less known and riskier biscuits market. In both cases, under the pressure of the switch from industry growth to maturity, leading family-owned firms responded to the consolidation process by introducing a number of innovative products that exposed the companies to a significant amount of market risk.

To date, no studies have demonstrated empirically how firm and market conditions driving innovation relate to both ownership and the industry life-cycle. Moreover, no ownership-driven mechanisms of innovation has been proposed to explain the predisposition of incumbent firms to modify their innovation activity along the industry life-cycle. This research attempts to address these gaps via a study on the influence of ownership on the innovation activities of European companies when the external competitive conditions shaped by the industry life-cycle are taken into account.

To address this issue, we first check the consistency of our dataset with results from extant literature on the firm innovation profile over the industry life-cycle. Specifically, after matching data on industry life-cycle and firm-level innovation, we test whether different innovation profiles, i.e. product and process innovation, prevail along the industry life-cycle (McGahan and Silverman, 2001). Secondly, we investigate whether the innovation profiles of incumbents change from growth to maturity when ownership is explicitly taken into account. In detail, we test if the adoption of risky innovations is more sensitive to the probability of exit driven by the shakeout for those owners who are mostly concerned with survival and permanence in the industry, like family firms. Finally, given the coexistence of external managers and family managers in the sub-sample of family firms, we provide evidence on the different response of the family ownership and the family management to the survival concerns of the owners when industry enters maturity.

The industry shakeout and the onset of maturity will be used to identify the exogenous change in the probability of survival that influences innovation. When substantial, this change in the chances of survival may push even risk-avoiding owners to accept a substantial risk in order to keep the benefits of control. As new product introduction or R&D can be perceived as innovation strategies riskier than process or organisational innovation, different types of innovative activity will be used to identify the change in the innovation risk profile during maturity.

To empirically test our predictions, we draw information from three main sources: (i) the EU-EFIGE Bruegel-UniCredit survey, which provides information about firm ownership, product and process innovations for a sample of 14,759 European manufacturing firms for the period 2007–2009; (ii) the BvD-Amadeus database, offering sample firms balance-sheet data for the years 2007–2009; (iii) the Eurostat database, which provides times series data on production values used to identify the life-cycle stages for a large number of industries (177 sectors using 4-digit NACE classification) in seven European countries in the period 1995–2013.[1]

By way of preview, consistently with the well-known industry life-cycle paradigm (McGahan and Silverman, 2001; Agarwal and Gort, 1996; Agarwal and Gort, 2002), estimation results confirm that firms focus on product-oriented innovation during the growth stage of the industry life-cycle and on process-oriented innovation during the maturity phase.

However, when firm ownership is taken into account, we find that this general pattern is strongly reversed by the shifts from growth to maturity, but only for family firms. In particular, while the innovation activity of family owners does not appear different to other owners during the growth stage, it does look very different during maturity, as family firms are significantly more prone to introduce risky product innovations during maturity than other owners. Controls for firm size, financial resources and other firm-specific variables, together with an explicit consideration of managerial ability, help in rejecting the hypothesis that family firms rely on product innovation for the inferior ability to manage process and organizational innovation. In addition, empirical estimates that separately consider the influence of family ownership and family management show that the risk-taking behavior during maturity is mainly associated with family ownership, not management. By contrast, family management is mostly associated with a risk-avoiding behavior during maturity, except in the case of experienced family CEOs.

To sum up, the paper shows that when external conditions threaten firm survival, like during maturity and shakeout, and compromise the possibility of transferring the firm down the generations, family owners tend to introduce more risky innovations. In providing this evidence, the paper contributes to the current literature along several dimensions. *First*, it empirically extends the literature on industry life-cycle by using firm-level data. Consistently with Bos et al. (2013) and ample previous literature (Abernathy and Utterback, 1975; Gort and Klepper, 1982, and Klepper, 1996), we find support for the hypothesis that firms focus on product-oriented innovation during the growth stage of the industry life-cycle, and on process-oriented innovation during the maturity phase of industry evolution.[2] However, we test the industry life-cycle model through a richer dataset compared to previous studies (Filson, 2001; McGahan and Silverman, 2001; Bos et al., 2013), covering more disaggregated industries (177 sectors at the four-digit NACE level) and using, for the first time, firm-level data on technological innovation (product- and process- oriented) matched with fine-grained sectoral life-cycles. *Second*, we contribute to the literature on firm ownership and technological innovation (Munari et al., 2010; Schmid et al., 2014; Minetti et al., 2015) by employing more detailed innovation measures (distinguishing between product-oriented and process-oriented innovation), and by accounting for the role played by industry dynamics in shaping the firm ownership-innovation link. In this sense, to the best of our knowledge, this is the first paper showing that the impact of firm ownership on innovation is significantly affected by the industry life-cycle stage in which the firm operates. This result

[1] We follow Bernard et al (2010) for the identification of different industries, sectors and products using 2-digit, 4-digit and 5-digit classification codes, respectively. As the literature has mainly used the term industry in the empirical analysis of the life-cycle, in the paper we also use the term industry even when sector should be used.

[2] The large body of evidence on product innovation during the growth stage of the industry is contrary to some studies on the nature of innovation over the life-cycle that use industry data (Filson, 2001; McGahan and Silverman, 2001).

has significant implications for the understanding of the innovation activity across regions and countries. Given the large differences in the ownership structure of the industries between and within countries, i.e. at regional level, and even by firm size and firm age, our focus on ownership looks promising in helping to explain the large variability in the innovation activity observed in different economic environments. *Third*, we extend the contribution of Tavassoli (2015) on the importance of firm-level innovation determinants over the industry life-cycle stages by considering firm ownership as a crucial factor, in particular when industry conditions selectively affect owners in their strategic decisions. *Fourth*, we contribute to the extensive and growing literature on family businesses (Bertrand and Schoar, 2006; Villalonga and Amit, 2006) by providing additional evidence on the innovative behavior of family firms. Consistently with Friedman et al. (2003) and Villalonga and Amit (2010), we provide support in explaining why family firms are found to be more resilient and innovative than non-family firms in industry downturn, because of their reaction to changes of external risk conditions. We also complement Thomsen and Pedersen (2000) by introducing an industry-related mechanism that explains why family businesses are less likely than non-family firms to undertake investment programs to exploit economies of scale (such as process innovation strategies), and more likely to pursue niche strategies related to flexibility or differentiation, such as product innovation. Finally, we add to Chrisman and Patel (2012) and Patel and Chrisman (2014) by showing that the innovative behavior of family firms may depend on exogenous variations in the conditions prevailing in the industry life-cycle, instead of on individual past results or below-expectation performance.

The rest of the paper is organized as follows. In Section 2 we review the literature on industry life-cycle, technological innovation and firm ownership, and formulate our testable hypotheses. Section 3 describes the dataset, the variables and the method adopted in the econometric analysis. Section 4 presents the empirical results, and Section 5 concludes by discussing the contributions and also some limitations of the paper.

## 2. Theory and hypotheses

### 2.1. Industry life-cycle and the type of innovation

The current theory has highlighted differences in the innovative behavior of firms across phases of the industry life-cycle (Henderson and Clark, 1990; O'Reilly and Tushman, 1997; McGahan and Silverman, 2001). During the growth stage, when firm heterogeneity is high, unstable consumer preferences promote product innovation and proliferation. Conversely, in mature industry sectors, where products are more standardized and the competitive scenario is characterized by efficiency-based competition, firms are more likely to focus on process innovation. Two important implications originate from these theories. The first implication is that innovation is high during the early stages of industries, but it decreases as industries mature (Abernathy and Utterback, 1978; McGahan and Silverman, 2001; Bos et al., 2013). The second is that innovation tends to be product-oriented during the emergent phase of industry development, whereas it is mostly focused on process during the maturity phase (Abernathy and Utterback, 1978; Anderson and Tushman, 1990; Cohen and Klepper, 1996; McGahan and Silverman, 2001; Bos et al., 2013).

Despite the relevant implications of these statements, the empirical evidence on this issue is still far from being completely settled. Important findings in support of a life-cycle theory of innovation have been provided by many empirical studies, but conclusive evidence based on micro-level data is still missing. Comin and Mulani (2009) show that industry R&D is positively correlated with firm volatility and high entry rates, i.e. two important structural features that characterize the growth stage of the industry life-cycle. Using entry into industry as a proxy for industry growth, Acs and Audretsch (1990) and Geroski (1991) also find a positive association between increasing market competition, measured by high rates of firm entry, and technological innovation. McGahan and Silverman (2001) employ patenting activity of US publicly traded firms (again at the industry level) to investigate whether innovation declines during the mature phase of the industry life cycle. Their results indicate that the general level of patenting activity is not lower in mature industries than in emerging sectors, and that there is not a shift from product to process innovation with industry maturity. Similar findings have been provided by Huergo and Jaumandreu (2004), which use firm age as a proxy for industry evolution.[3] By analyzing how the probability of innovation varies by firm age, Huergo and Jaumandreu (2004) show that product and process innovations are likely to evolve in tandem over firm evolutionary phases. Further evidence is provided by Filson (2001; 2002). By analyzing five US industries (i.e. the early automobile industry, the PC industry, the rigid disk drive industry, the computer monitor industry and the computer printer industry), the author confirms the conventional wisdom about technological change over the industry life-cycle: the rate of quality improvement is highest at the early stage of industry development, while the rate of cost improvement is higher as the industry matures. By extending the analysis to 21 European manufacturing sectors, Bos et al. (2013) corroborate these findings: innovation is high when the industry is young, product innovation decreases with industry maturity, while process innovation increases as the industry matures.

Given this contrasting evidence, we first investigate in our data the basic relationship between product/process innovation and industry life-cycle stage put forward by the main literature (Henderson and Clark, 1990; O'Reilly and Tushman, 1997; McGahan and Silverman, 2001). As we use a unique dataset on product and process innovation for a large sample of European manufacturing firms, this test provides support for the consistency of our empirical analysis with the extant empirical literature. Hence, we test the following well-accepted hypothesis:

**Hypothesis 1.** *Firms focus on product-oriented innovation during the growth stage of the industry life-cycle, and on process-oriented innovation during the maturity phase of industry evolution.*

### 2.2. Innovation, ownership and the influence of industry maturity

During the last decades, the number of studies analyzing the link between corporate governance and technological innovation has increased substantially. The literature has widely investigated the role of ownership concentration, large shareholders, corporate governance structures and practices in influencing firm innovation decisions (Bushee, 1998; David et al., 2001; Hall and Soskice, 2001; Coriat and Weinstein, 2002; Hoskisson et al., 2002; Lee and O'Neil, 2003; Tylecote and Ramirez, 2006; Lazonick, 2007; Munari et al., 2010; Schmid et al., 2014). Despite the widespread research, however, the current evidence on the relationship between innovation and ownership is still mixed and unconvincing. Besides, no literature directly addresses the issue of how industry maturity reshapes the innovation profile of the firm when company ownership is explicitly taken into account.

The basic idea behind the differential impact of ownership on innovation is that investment in innovation differs substantially from investment in tangible assets. First, new technologies require expertise and scientific knowledge (Hall and Lerner, 2010), they are long-term

[3] Several papers have analyzed the link between firm age and innovative behavior. For a sample of US firms, Hansen (1992) shows that firm age negatively affects the number and share of new products, and Doms et al. (1995) find that mature firms are more likely to survive when implementing new process technology.

oriented and characterized by high risk and uncertain outcome (Holmstrom, 1989; Scherer and Harhoff, 2000).[4] Second, technological innovation is characterized by high levels of information asymmetry: it is hard for third parties to understand its potential implications, and few interim signals, such as cash flows, are available on its outcome (Aboody and Lev, 2000; Rajan and Zingales, 2001; Minetti et al., 2015). Finally, innovations have low salvage value, as the assets are often intangible or highly firm-specific (Hall and Khan, 2003; Minetti et al., 2015). All these features make innovation highly dependent on incentives and preferences specific to individual owners, who can react differently to similar industry life-cycle changes.

#### 2.2.1. Institutional and financial ownership

By examining the relationship between R&D spending and institutional ownership over a 10-year period for 129 firms based in four research-intensive industries, Hansen and Hill (1991) find that higher levels of institutional ownership are associated with greater R&D expenditures. Similarly, for the universe of US publicly traded firms, Aghion et al. (2013) show that there is a robust positive association between innovation and institutional ownership. Controversial results have been instead provided by Bushee (1998) and Minetti et al. (2015). Bushee (1998) shows that managers are less likely to cut R&D expenditure when institutional ownership is high, but are more likely to do so when the institutional owners have high portfolio turnover and engage in momentum trading. Using data for 20,000 Italian manufacturing firms, Minetti et al. (2015) find evidence that companies controlled by institutions are less likely to invest in product and process innovation, although the benefits of ownership increase with their equity stakes.

The ambiguous evidence summarized so far also persists when the influence of institutional ownership is evaluated under the change from growth to maturity. Since these firms have a deliberately short investment holding period and are often assessed by the financial press and analysts on the ground of their short-term performance, financial owners are expected to have shorter investment horizons (Minetti et al., 2015). This should make their investments in innovation less likely to occur during shakeout, especially when financial performance is already hit by the onset of the maturity phase of the industry life-cycle. Therefore, we set the following hypothesis:

**Hypothesis 2a.** *Financial ownership negatively affects technological innovation during the maturity stage of the industry life-cycle;*

On the other hand, as financially-controlled companies are found to have better performances and management practices than other firms (Bloom and Van Reenen, 2010), they may be more able to identify growth opportunities arising from investments in innovation, even during maturity. Therefore, we put forward the following competing hypothesis:

**Hypothesis 2b.** *Financial ownership positively affects technological innovation during the maturity stage of the industry life-cycle.*

#### 2.2.2. State ownership

A small part of the empirical literature has focused on the role of state ownership in influencing firms' technological innovation. Despite the crucial theoretical and practical implications, the existing evidence is still limited and controversial. Through an in-depth analysis of corporate R&D units of seven companies privatized in Italy and France during the 1990s, Munari (2002) finds that the divestiture by the state is associated with a significant reduction of resources devoted to R&D. Conversely, in a study on European listed firms, Munari et al. (2010) do not find any statistically significant relationship between the state control share and R&D intensity.

Unlike other types of ownership, innovation decisions of state-owned companies should be less dependent on industry dynamics. State-owned firms are often set up, or nationalized, to achieve a wider set of objectives, such as the maximization of social welfare through the control of possible market asymmetries (Vickers and Yarrow, 1988; Munari et al., 2010). Innovation activities within state-controlled firms may be aimed at satisfying the general goal of generating the public good of knowledge, or may be directed towards specific business objectives, particularly when government intervention is occurring in industries and areas of strategic relevance for the country (Molas-Galart and Tang, 2006; Munari et al., 2002; Munari et al., 2010). In addition, by being only marginally affected by the market discipline, state-controlled companies are rarely called upon to justify possible below-average or negative returns, as they are compensated by subsidizing products and services to the greater public (Munari et al., 2010). These characteristics may make state-owned firms less likely to change their innovation strategies during the maturity stage of the industry life-cycle, when the risk of failure increases substantially. As they are not strictly profit-maximizers, they may keep investing in technological innovation also when the shake-out phase occurs. Hence, we test the following hypothesis:

**Hypothesis 2c.** *State ownership positively affects technological innovation during the maturity stages of the industry life-cycle.*

#### 2.2.3. Family ownership

Driven by the fact that many corporations around the world are dominated by families, several studies have focused on the influence of family ownership on innovation decisions. Chen and Hsu (2009) analyze a sample of Taiwanese firms and provide evidence of the existence of a negative family ownership-R&D investment relationship. Similarly, by examining a sample of 1000 firms publicly traded in six European countries, Munari et al. (2010) find that higher shareholding by families is negatively associated with R&D investment. Analogous results have been provided by Munoz-Bullon and Sanchez-Bueno (2011) for a sample of Canadian listed corporations, and by Anderson et al. (2012). In particular, by exploring the relation between family ownership and corporate investment policy, Anderson et al. (2012) find that family firms devote less capital to long term investments than firms with diffuse ownership structures. Moreover, when distinguishing long term investment into its two components of R&D and capital expenditure, it results that family firms, relative to non-family businesses, prefer investing in physical assets relative to riskier R&D projects. Mixed results have been shown by Block (2012), who analyzes R&D spending for a sample of US family and founder firms, and finds that while family ownership decreases the level of R&D intensity, ownership by lone founders has a positive effect. By contrast, opposite findings have been provided by the most recent studies. By employing a large-scale, biannual survey among listed German firms, Schmid et al. (2014) find that R&D intensity is higher in firms that are actively managed by the family, while the impact of family control (via voting rights) is negative, but mostly not significant. Similarly, Minetti et al. (2015), for a sample of small and medium-sized Italian manufacturing firms, show that family firms are significantly more likely to introduce both product and process innovation.

When industry matures, the rate of firm failure increases sharply and the number of firms begins to fall. Exit from industry becomes a probable outcome of the industry shakeout. As a consequence, family firm decision makers may see risky investments with long-term payoffs (as investments in product innovation) as a necessary way to preserve their wealth (Gomez-Mejia et al., 2010; Munari et al., 2010) and make their firms more resilient (Friedman et al., 2003; Villalonga and Amit, 2010).[5] In this context, we expect that family firms are more

[4] Many R&D projects produce negative cash flow in the beginning and became profitable only in a later phase (Munari et al., 2010; Schmid et al., 2014).

[5] Sirmon and Hitt (2003) suggest that patient capital, i.e. financial capital that

likely to introduce risky product innovation during maturity. Hence, we test the following hypothesis:

**Hypothesis 2d.** *Family ownership positively affects product innovation during the maturity phase of the industry life-cycle.*

In addition, we expect that the innovation propensity increases with the time elapsed from the inception of maturity, as the probability to exit the market grows with the consolidation of the industry. Therefore, we test the following hypothesis:

**Hypothesis 2e.** *The family firm propensity to introduce product innovations increases with the years elapsed since the inception of industry maturity.*

#### 2.2.4. Family management

A peculiar feature of the governance of family firms is that they are usually managed by family members, instead of external managers as in the case of industrial, financial and state-owned companies. According to the EFIGE survey, the share of family-owned and managed firms in major European countries ranges between 62.2 per cent in France to 83.9 per cent and 84.5 per cent respectively in Italy and Germany (Bugamelli et al., 2012), whereas the remaining share of family firms is run by external CEOs.[6] While external CEOs are assumed to adopt a similar response to maturity regardless the owner identity – as they all are hired from an external market for talents - the reaction of family CEOs to industry maturity may be highly heterogeneous and result in very divergent outcomes. On the one hand, family managers may even promote the adoption of risky innovation strategies during maturity, given their strong involvement in the company and higher risk propensity in times of crisis (Gomez-Mejia et al., 2007; Hoskinsson et al., 2017). On the other hand, however, the limited pool of talents available within the family, or the rivalry among family members, may adversely affect the managerial quality and business skills of family CEOs, who prefer safe innovation strategies and low risk initiatives (Schulze et al., 2001). This situation can curb the innovation potential of family firms during maturity (Schulze et al., 2001; 2003; Villalonga and Amit, 2006; Schmid et al., 2014). Thus, we expect family managers to promote risky product innovation during maturity, but only when their individual abilities and business skills are similar to those of external CEOs. Therefore, we set the following hypothesis:

**Hypothesis 3.** *Family managers promote product innovation in family firms during maturity, conditional on their managerial ability and business skills*

## 3. Data and method

### 3.1. Sample

We build our dataset by drawing information from three main sources: (i) the EU-EFIGE Bruegel-UniCredit survey on "European Firms in a Global Economy"; (ii) the BvD-Amadeus database; (iii) the Eurostat database. The EU-EFIGE survey collects detailed qualitative and quantitative information about firm ownership and governance structure, workforce characteristics, innovation and internationalization activities, financial conditions, market structure and competition.[7] The dataset covers a representative sample (at the country and industry level) of 14,759 manufacturing firms with more than ten employees from seven European countries: Austria, France, Germany, Hungary, Italy, Spain and UK. As the survey was run in early 2010, information is mostly collected as a cross-section for the year 2008, although some questions cover the period 2007–2009. To all the surveyed firms, we attach balance-sheet data for the years 2007–2009 provided by BvD-Amadeus, the most comprehensive and widely used source of financial information for public and private enterprises in Europe. Finally, data on production values, used to identify industry life-cycle stages for a large number of sectors (177 sectors at 4-digit NACE classification) in seven European countries, are obtained from the Eurostat website. To match the business-unit data provided by BvD-Amadeus with the European industry-level information, we have used fine-grained production value data available from Eurostat at the four-digit NACE codes.

By merging the three datasets, and considering only those sectors with continuous coverage for the period 1995–2013, we end up with a final sample of 9602 companies operating in 177 industries during the period 2001–2009. Table 1 reports some descriptive statistics (see Appendix 1 for more details on the variables). The sample is mainly composed of small- and medium-sized enterprises and established companies. The average firm size is small to medium, with a mean of 70 employees and a median of 27; the surveyed firms have been in business for 24 years on average. The majority of the firms are located in Germany, Italy and Spain (more than 80% of the total), while 12% of companies operate in UK, 3.5% in Hungary and 2.8% in Austria.

### 3.2. Definition of the variables

#### 3.2.1. Product and process innovation

To measure technological innovation and distinguish product-oriented and process-oriented innovations, we use firms' responses to the EFIGE survey. The questions asking about the type of innovation carried out by the sample firms (from C14 to C17 of the EFIGE survey) are reported in Appendix 1. Starting from product-oriented innovations, we define: (i) *Market product innovation*, a dummy variable equal to one if the firm introduced either a new good or a significantly improved product onto the market before its competitors, and zero otherwise; (ii) *Firm product innovation*, a dummy variable equal to one if the firm introduced either a new good or a significantly improved product that was already available in the market from its competitors, and zero otherwise; (iii) *Patent applications*, a dummy variable equal to one if the firm either applied for a patent, registered an industrial design, registered a trademark or claimed copyright, and zero otherwise. By contrast, as process-oriented innovations, we consider: (i) *Process innovation*, a dummy variable equal to one if the firm adopted either a new or a significantly improved production technology, and zero otherwise; (ii) *Organizational innovation*, a dummy variable equal to one if the firm introduced new organizational methods in its business practice, workplace organizations or external relations, and zero otherwise.

In the sample, half the firms reported product-oriented innovations: more specifically, over the three-year period covered by the survey, 30.5% of firms introduced some market product innovations, 48.3% invested in firm product innovation, 23.1% applied for a patent, claimed copyright or registered an industrial design or a trademark. As for the other types of innovation, 43.8% of sample firms introduced some process innovations, and 31.4% of firms invested in organizational innovation (Table 1).[8]

(*footnote continued*)
is invested without threat of liquidation for long periods, is a relevant factor explaining family firm innovation propensity.

[6] According to the EFIGE survey, the share of firms owned by a family in major European countries ranges from 80.0 per cent in France to 85.6 percent in Italy and 89.8 percent in Germany.

[7] For additional information about the EU-EFIGE survey, see Altomonte and Aquilante (2012).

[8] Employing self-reported data may generate concerns that the firms overstate or understate their innovations. However, as these data have been collected only for statistical purposes, firms should have had no incentive to overstate their innovations. Moreover, measurement errors in the dependent variables would bias the results only if systematically related to the explanatory variables (Minetti et al., 2015).

**Table 1**
Descriptive statistics and univariate tests.

| Variables | Full sample Mean | Std. Dev. | Growth Mean | Std. Dev. | Obs. | Maturity Mean | Std. Dev. | Obs. | *t-test* |
|---|---|---|---|---|---|---|---|---|---|
| *Industry life-cycle:* | | | | | | | | | |
| Growth | 0.190 | 0.393 | | | | | | | |
| Maturity years | 3.986 | 4.668 | | | | | | | |
| *Technological innovation:* | | | | | | | | | |
| Mkt product innovation | 0.305 | 0.460 | 0.309 | 0.462 | 1828 | 0.304 | 0.460 | 7774 | *−0.381* |
| Firm product innovation | 0.483 | 0.500 | 0.495 | 0.500 | 1828 | 0.481 | 0.500 | 7774 | *−1.064* |
| Patent applications | 0.231 | 0.422 | 0.261 | 0.439 | 1828 | 0.224 | 0.417 | 7773 | *−3.268* |
| Process innovation | 0.438 | 0.496 | 0.429 | 0.495 | 1828 | 0.441 | 0.496 | 7774 | *0.908* |
| Organizational innovation | 0.314 | 0.464 | 0.296 | 0.457 | 1828 | 0.318 | 0.466 | 7774 | *1.813* |
| *Firm ownership:* | | | | | | | | | |
| Family firm | 0.745 | 0.449 | 0.734 | 0.462 | 1720 | 0.765 | 0.445 | 7378 | *2.963* |
| Financial | 0.012 | 0.096 | 0.012 | 0.108 | 1720 | 0.009 | 0.093 | 7378 | *−1.122* |
| State | 0.003 | 0.047 | 0.003 | 0.058 | 1720 | 0.002 | 0.045 | 7378 | *−0.953* |
| Industrial | 0.239 | 0.414 | 0.251 | 0.426 | 1720 | 0.224 | 0.411 | 7378 | *−2.134* |
| *Control variables:* | | | | | | | | | |
| Size (Num. Employees) | 70.207 | 142.616 | 73.650 | 151.545 | 1315 | 69.319 | 140.224 | 5101 | *−0.938* |
| Firm age (Years) | 24.180 | 19.290 | 24.853 | 19.439 | 1815 | 24.022 | 19.252 | 7745 | *−1.643* |
| Ownership Share | 66.007 | 28.362 | 65.397 | 28.659 | 1754 | 66.152 | 28.291 | 7411 | *0.995* |
| Liquidity ratio | 1.361 | 1.295 | 1.268 | 1.173 | 1640 | 1.384 | 1.322 | 6726 | *3.496* |
| Diff. ROS | 0.005 | 0.059 | 0.006 | 0.058 | 1400 | 0.005 | 0.059 | 5477 | *−0.774* |
| High tech industry | 0.035 | 0.184 | 0.037 | 0.190 | 1763 | 0.035 | 0.183 | 7483 | *−0.539* |
| *Other variables:* | | | | | | | | | |
| Productivity | 52.479 | 29.373 | 53.616 | 30.058 | 1100 | 52.192 | 29.194 | 4349 | *−1.412* |
| CEO Age | 52.460 | 10.156 | 52.434 | 10.066 | 1820 | 52.592 | 10.217 | 7747 | *0.595* |
| CEO Foreign Experience | 0.221 | 0.415 | 0.213 | 0.410 | 1808 | 0.196 | 0.397 | 7691 | *−1.577* |
| *Country:* | | | | | | | | | |
| Austria | 0.028 | 0.165 | 0.053 | 0.223 | 1828 | 0.022 | 0.147 | 7774 | *−5.547* |
| France | 0.224 | 0.417 | 0.261 | 0.439 | 1828 | 0.215 | 0.411 | 7774 | *−4.089* |
| Germany | 0.188 | 0.391 | 0.111 | 0.314 | 1828 | 0.206 | 0.404 | 7774 | *10.952* |
| Hungary | 0.035 | 0.183 | 0.055 | 0.227 | 1828 | 0.030 | 0.170 | 7774 | *−4.393* |
| Italy | 0.198 | 0.399 | 0.194 | 0.395 | 1828 | 0.199 | 0.400 | 7774 | *0.556* |
| Spain | 0.209 | 0.406 | 0.223 | 0.417 | 1828 | 0.205 | 0.404 | 7774 | *−1.674* |
| UK | 0.119 | 0.324 | 0.104 | 0.305 | 1828 | 0.123 | 0.328 | 7774 | *2.332* |

*Notes:* All of the variables are defined in Appendix 1.

### 3.2.2. *Industry life-cycle*

As life-cycle curves are not directly observable, the identification of industry life-cycle stages requires some challenging estimations. A statistical approach widely used to model business cycles and recently adopted to industry life-cycle analysis (Karniouchina et al., 2013), is Hamilton's latent state regime switching method (Hamilton, 1989 – See Appendix 2).[9] Based on aggregate production value changes by industry (See Fig. 1 for examples), this approach allows to classify sectors into growth, maturity and decline stages and to account for multiple shifts back and forth from one stage to another. As our focus is on established companies and we are unable to get information about the exact birth of industries, our model omits the very initial stage of sector development. Moreover, as we are mainly interested in the growth and maturity stages, to avoid losing those observations related to declining industry sectors, we consider a wider definition of mature industries by including the decline phase into the maturity one.[10] For a better interpretation of our findings, we also exclude from the whole sample those industries with multiple shifts back and forth from one stage to another and those sectors with a reverse life-cycle (i.e. sectors experiencing a maturity or growth phase after a declining one).[11] Finally, as the results of estimated models may be dependent on the method used to identify the stages of the industry life cycle, we followed Tavassoli (2015) to check the consistency of the method by comparing the allocation of firms into different stages using a different identification method. In detail, we used the approach put forward by Mc Gahan & Silverman (2001) that considers maturity as the first year when the 3-year moving average of the number of firms in the industry is 3pp lower than the value in the previous 3-years. Growth was defined as a residual.[12] The results of the allocation of companies by stage using different allocation methods is discussed in Section 4.5.

As our innovation measures are cross-sectional variables referring to 2007–2009, in the multivariate analysis we focus on the industry stage registered in 2007, although we obtain information about the life-cycle stage for each year/country/sector combination for the whole period 1995–2013. In particular, we create an industry life-cycle dummy variable *Growth*, which is set equal to one if the industry was in the growth stage in 2007, and zero otherwise. In this last case, the variable is identified as *Maturity*. As the shake-out risk increases as maturity advances, an additional variable was created to gain additional insights about the relevance of survival concerns over time. This variable, named *Maturity years*, is a continuous variable computed as the number of years elapsed from the beginning of the maturity stage. This variable has been explicitly calculated to test if and how intensely the firm's innovative behavior changes over time when the industry goes deep into the maturity stage.

The importance of the maturity stage analysis is supported by the

[9] Several studies have developed empirical tools for the identification of the industry-life cycle stages. These methods are primarily based on net entry (Klepper and Graddy, 1990; Karlsson and Nystrom, 2003), rate of growth in the number of firms (McGahan and Silverman, 2001), innovation intensity together with the size of the dominant innovators (Audretsch and Feldman, 1996), maturity index (Neffke et al., 2011), and employment growth (Otto and Fornahl, 2010). See Tavassoli (2015) for a detailed literature review.

[10] Estimation results do not significantly change when we exclude declining sectors from the definition of mature industries.

[11] Evidence on the innovation profile in these sectors is discussed in the robustness Section.

[12] We thank one referee for suggesting this robustness check.

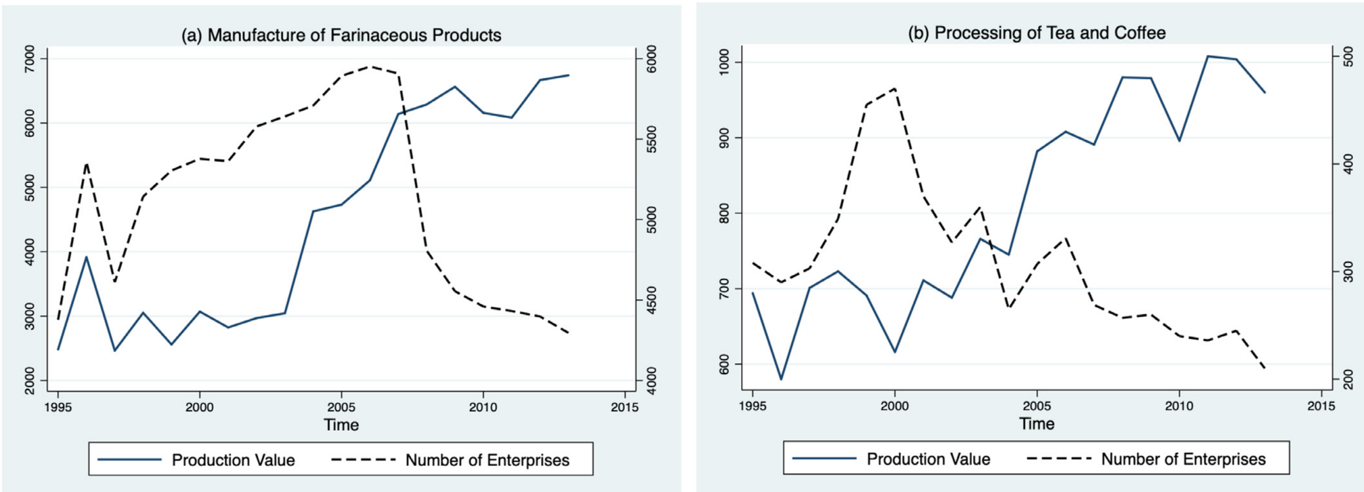


**Fig. 1.** Evolution of value of production and number of enterprises for selected industries.

summary statistics reported in Table 1: in our reference year (2007), 19% of firms operate in growing industries, whereas 81% of companies operate in mature sectors.[13] Table 1 also reports some univariate tests for the subsamples of firms operating in growing and mature industries. Consistently with both the industry life-cycle theory and our theoretical predictions, summary statistics indicate that firms introduce more product-oriented innovation during growing periods and more process-oriented innovation during the maturity stage of the industry life-cycle. More specifically, during the growth stage, firms invest in market product innovation in 30.9% of cases, firm product innovation in 49.5% of cases, and patent applications in more than 26% of cases. Conversely, during the maturity phase, the surveyed firms are shown to introduce mainly process and organizational innovations (respectively, in 44.1 and 31.8% of cases).

### 3.2.3. Firm ownership

The EFIGE survey asks each firm to report detailed ownership information, such as the type and equity share of the main shareholders. Hence, to define ownership (family firms, financial-owned companies, state-owned enterprises, and industrial holdings, which is our reference category), we directly rely on self-reported data of firms. A specific consideration is needed for family ownership, as theoretical and empirical studies have proposed definitions based on different criteria, like ownership shares, family involvement in the business, and some combinations of the two criteria (La Porta et al., 1999; Faccio and Lang, 2002; Anderson and Reeb, 2003; Barontini and Caprio, 2006; Villalonga and Amit, 2006). As for this ownership, based on questions A20 and A21 of the EFIGE survey, we further classify (1) family owned firms as those companies directly or indirectly controlled by an individual or a family; (2) family managed firms as those companies run by the individual who owns or controls the firm, or by a member of the controlling family.[14] From survey questions, we create the following ownership variables: (i) Family firm, a dummy variable equal to one if the firm is family owned (regardless of the management), and zero otherwise; (ii) Financial company, a dummy variable equal to one if the firm's main shareholder is a financial institution, and zero otherwise; (iii) State-owned company, a dummy variable equal to one if the firm's main shareholder is a public entity, and zero otherwise; (iv) Industrial company, a dummy variable equal to one if the firm's main shareholder is an industrial firm, and zero otherwise (see Appendix 1 for a detailed description of the survey questions). As reported in Table 1, in our sample, 74.5% of firms are family owned, 1.2% are controlled by financial institutions, 0.3% are owned by public entities, and almost 24% are industrial companies.

Descriptive statistics for the different subsamples of firms are shown in Table 2. In terms of technological innovation, all types of companies focus mainly on firm product and process innovation: during the years of the survey, these innovations have been introduced by more than 44% of family firms, almost 60% of financial companies, at least one third of state-owned corporations and more than 40% of industrial firms. Looking at the other firm-specific characteristics, summary statistics indicate that family firms are significantly smaller, older and less productive than financial-controlled firms, state-owned corporations, and industrial companies. Conversely, firms owned by public entities are shown to be larger (with, on average, 250 employees), younger, and with more concentrated ownership shares when compared to the other types of companies. Finally, coming to the geographical distribution, family firms are mainly located in Germany, Italy and Spain, financial-controlled companies operate primarily in France and Germany, state-owned corporations are mainly located in Germany, and industrial firms are mainly French ones.

### 3.2.4. Control variables

To correctly test our hypotheses and mitigate the omitted variable concern associated with the cross-sectional structure of our dataset, we control for a large set of possible confounding effects.

First, several studies show that the likelihood of being innovative is positively related to the size of firms (Acs and Audretsch, 1987; Cohen and Klepper, 1996; Patel and Pavitt, 1995; Mohnen et al., 2006). The access of large firms to finance and scale economies increases both advertisement power and scope economies for innovation activities (Scherer, 1965; Comanor, 1967; Tavassoli, 2015). Hence, in our specification we control for firm size (Size), proxied by the total number of employees. Second, as suggested by the current literature (Hansen, 1992; Schmid et al., 2014; Minetti et al., 2015), we control for firm age (Firm age, measured by the number of years for firm's birth, expressed in logarithm). Although older organizations may undertake innovation investments less frequently than younger firms because of inertia, the need to renew the business may increase with company age (Coad, 2018; Huergo and Jaumandreu, 2004; Kellermanns and Eddleston, 2006). Moreover, the information opaqueness characterizing

[13] More specifically, 67 percent of firms operate in mature industries and 14 percent of companies operate in declining manufacturing sectors.

[14] Questions A20 and A21 of the EFIGE survey read as follows:

A20. *Is your firm directly or indirectly controlled by an individual or a family-owned entity? (yes/no).*

A21. *Is the CEO of your firm (i) the individual who owns or controls the firm, or a member of the family that owns/controls it? (ii) a manager recruited from outside the firm? (iii) a manager appointed within the firm?*

**Table 2**
Descriptive statistics by firm ownership.

| Variables | Family firm Mean | Std. Dev. | Financial Mean | Std. Dev. | State Mean | Std. Dev. | Industrial Mean | Std. Dev. |
|---|---|---|---|---|---|---|---|---|
| *Technological innovation:* | | | | | | | | |
| Mkt product innovation | 0.303 | 0.460 | 0.460 | 0.501 | 0.333 | 0.483 | 0.298 | 0.458 |
| Firm product innovation | 0.488 | 0.500 | 0.586 | 0.495 | 0.381 | 0.498 | 0.449 | 0.497 |
| Patent applications | 0.231 | 0.421 | 0.437 | 0.499 | 0.238 | 0.436 | 0.204 | 0.403 |
| Process innovation | 0.444 | 0.497 | 0.563 | 0.499 | 0.333 | 0.483 | 0.405 | 0.491 |
| Organizational innovation | 0.326 | 0.469 | 0.402 | 0.493 | 0.238 | 0.436 | 0.270 | 0.444 |
| *Control variables:* | | | | | | | | |
| Size (Num. Employees) | 59.009 | 120.524 | 128.328 | 177.388 | 250.750 | 365.111 | 81.463 | 165.430 |
| Firm age (Years) | 24.969 | 19.792 | 21.384 | 18.150 | 19.550 | 20.562 | 21.557 | 17.127 |
| Ownership Share | 66.129 | 27.255 | 71.549 | 27.639 | 90.150 | 16.503 | 61.185 | 30.499 |
| Liquidity ratio | 1.367 | 1.335 | 2.102 | 2.488 | 2.264 | 2.214 | 1.330 | 1.151 |
| Diff. ROS | 0.006 | 0.057 | −0.002 | 0.055 | 0.017 | 0.070 | 0.004 | 0.063 |
| High tech industry | 0.032 | 0.175 | 0.094 | 0.294 | 0.100 | 0.308 | 0.038 | 0.191 |
| *Other variables:* | | | | | | | | |
| Productivity | 50.379 | 27.379 | 69.973 | 47.313 | 75.816 | 46.478 | 54.570 | 30.422 |
| CEO Age | 52.709 | 10.523 | 50.409 | 9.478 | 52.174 | 9.408 | 52.052 | 9.502 |
| CEO Foreign Experience | 0.203 | 0.402 | 0.527 | 0.501 | 0.455 | 0.504 | 0.236 | 0.425 |
| *Country:* | | | | | | | | |
| Austria | 0.033 | 0.179 | 0 | 0 | 0.143 | 0.359 | 0.010 | 0.098 |
| France | 0.182 | 0.386 | 0.241 | 0.430 | 0.095 | 0.301 | 0.330 | 0.470 |
| Germany | 0.220 | 0.414 | 0.264 | 0.444 | 0.429 | 0.507 | 0.101 | 0.301 |
| Hungary | 0.026 | 0.158 | 0.046 | 0.211 | 0 | 0 | 0.070 | 0.255 |
| Italy | 0.208 | 0.406 | 0.092 | 0.291 | 0.048 | 0.218 | 0.184 | 0.387 |
| Spain | 0.224 | 0.417 | 0.149 | 0.359 | 0.048 | 0.218 | 0.157 | 0.364 |
| UK | 0.107 | 0.309 | 0.207 | 0.407 | 0.238 | 0.436 | 0.148 | 0.356 |

*Notes:* All of the variables are defined in Appendix 1.

young firms (due to the lack of established track records) may hinder their ability to finance innovation projects. Third, innovation decisions may be significantly affected by ownership concentration. It is sometimes argued that firms with dispersed ownership have more incentives to engage in innovation because they diversify its risk across a large number of investors (Aghion et al., 2013; Minetti et al., 2015). The conflicts of interest between main owners and smaller shareholders characterizing highly concentrated companies, instead, may produce serious distortions in firms' decisions, which could be detrimental to complex, long-term investments such as innovation (Claessens et al., 2002; Minetti et al., 2015). For this reason, we include the ownership share of the first shareholder (Ownership share) as an additional control variable. Our fourth and fifth control variables are proxies for firm liquidity and profitability (Liquidity ratio, computed as current assets over current liabilities; Diff. ROS, computed as the difference between the firm ROS (Return on Sales) and the median ROS of the same industry, size class and region). Although successful businesses may reduce managers' willingness to invest in innovation, good performances and high liquidity may provide slack resources that encourage the exploration of new strategic options, such as investments in innovation.

Finally, we control for industry-specific effects and regional characteristics by including a proxy for the technological intensity of the industry sector (High tech industry, a dummy variable equal to one if the firm's major industry is high tech, and zero otherwise) and regional dummies (at the NUTS 2 level).[15]

### 3.3. Baseline regression

To test our theoretical hypotheses, we use a simple empirical model that estimates the probability of firms introducing technological innovation as follows:

$$y_i = \begin{cases} 1 \text{ if } y_i^*>0 \\ 0 \text{ otherwise} \end{cases} \tag{1}$$

$$y_i^* = \alpha X_i + \beta Z_i + u_i \tag{2}$$

where $y_i$ represents the observed dependent variables, and denotes, alternatively, one of the technological innovation measures described in Section 3.2.1 (i.e. Market product innovation, Firm product innovation, Patent applications, Process innovation and Organizational innovation); $y_i^*$ is the associated latent variable; $X_i$is the vector of explanatory variables, i.e. industry life-cycle stage and firm ownership (as defined in Section 3.2.2 and Section 3.2.3, respectively); $Z_i$ is a vector of exogenous covariates; $u_i$ is the error term.

As our dependent variables are dummy variables taking values zero and one, we estimate Eq. (2) by maximum likelihood probit regressions. Table 3 displays the correlation matrix.

## 4. Results

### 4.1. Industry life-cycle, product-oriented and process-oriented innovation

We initially investigate whether innovative behavior of firms varies over the industry life-cycle. Specifically, we test whether firm innovation is product-oriented during the growth phase of industry and process-oriented during maturity (Hypothesis 1). The estimated marginal effects are reported in Table 4. In columns (1)–(5), we employ the Growth dummy variable to analyze the impact of the growth phase on product-oriented and process-oriented innovations. As shown in Table 4, during the growth stage of industry evolution, firms are 3.4% more likely to invest in firm product innovation (statistically significant at 90%), 7% more likely to apply for a new patent (statistically significant at 99%), and less likely to promote process and organizational innovation initiatives (although not statistically significant). These results provide support for Hypothesis 1, which predicts a higher product-oriented innovation activity during the growth stage of industry development (Growth = 1). In order to check the robustness of these findings and gather additional insights about the impact of industry evolution on firm innovation activities, in columns (6)–(10) we use a different proxy for the industry-life cycle stage, i.e. the continuous variable Maturity years, that indicates the years elapsed since the inception of maturity. The marginal effects reported in Table 4 (columns

[15] All of the variables are defined in Appendix 1.

**Table 3**
Correlation matrix.

| Variables | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) | (17) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mkt product innovation | 1.000 | | | | | | | | | | | | | | | | |
| Firm product innovation | 0.675 | 1.000 | | | | | | | | | | | | | | | |
| Patent applications | 0.328 | 0.338 | 1.000 | | | | | | | | | | | | | | |
| Process innovation | 0.152 | 0.200 | 0.121 | 1.000 | | | | | | | | | | | | | |
| Organizational innovation | 0.182 | 0.253 | 0.131 | 0.494 | 1.000 | | | | | | | | | | | | |
| Family firm | −0.001 | 0.020 | 0.011 | 0.033 | 0.017 | 1.000 | | | | | | | | | | | |
| Financial | 0.003 | −0.003 | 0.014 | 0.014 | 0.020 | −0.062 | 1.000 | | | | | | | | | | |
| State | 0.024 | 0.007 | 0.017 | −0.003 | 0.010 | −0.025 | −0.004 | 1.000 | | | | | | | | | |
| Industrial | −0.012 | −0.045 | −0.034 | −0.045 | −0.026 | −0.861 | −0.050 | −0.021 | 1.000 | | | | | | | | |
| Growth | 0.020 | 0.036 | 0.059 | −0.001 | −0.017 | −0.015 | 0.006 | 0.008 | 0.014 | 1.000 | | | | | | | |
| Maturity years | −0.033 | −0.070 | −0.087 | −0.035 | −0.016 | 0.008 | −0.016 | 0.005 | 0.009 | −0.423 | 1.000 | | | | | | |
| Size (Num. Employees) | 0.118 | 0.141 | 0.201 | 0.078 | 0.093 | −0.134 | 0.062 | 0.067 | 0.028 | 0.007 | −0.060 | 1.000 | | | | | |
| Firm age (Years) | 0.033 | 0.045 | 0.066 | −0.017 | −0.008 | 0.018 | −0.007 | 0.003 | −0.025 | 0.023 | −0.013 | 0.202 | 1.000 | | | | |
| Ownership Share | −0.014 | −0.025 | −0.011 | −0.054 | −0.044 | 0.037 | −0.011 | −0.011 | −0.032 | −0.005 | 0.038 | 0.015 | 0.134 | 1.000 | | | |
| Liquidity ratio | −0.038 | −0.052 | −0.032 | −0.018 | −0.018 | −0.009 | 0.017 | 0.052 | −0.002 | −0.027 | 0.020 | −0.016 | 0.097 | 0.042 | 1.000 | | |
| Diff. ROS | 0.025 | 0.012 | 0.006 | 0.045 | 0.038 | 0.026 | −0.012 | 0.004 | −0.023 | 0.003 | 0.003 | −0.019 | −0.009 | 0.020 | 0.227 | 1.000 | |
| High tech industry | 0.069 | 0.097 | 0.074 | 0.012 | 0.007 | −0.032 | 0.006 | 0.050 | −0.005 | −0.015 | −0.011 | 0.085 | 0.037 | 0.014 | 0.028 | −0.019 | 1.000 |

*Notes:* All of the variables are defined in Appendix 1.

6 to 10) indicate that as the maturity phase advances, firms are more likely to reduce product-oriented innovation and to increase their investments in process-oriented and organizational innovation initiatives. In particular, as the industry enters the maturity phase, firms are less likely to invest in new-to-the-market product innovation (the estimated marginal effect is −0.002 statistically significant at 90%), less likely to promote new-to-the-firm product innovation initiatives (the estimated marginal effect is −0.004 statistically significant at 95% level) and less likely to apply for new patents (the estimated marginal effect is −0.006 statistically significant at 99% level). Conversely, and consistently with the industry life-cycle theory, the probability of promoting organizational innovation activities are found to increase during maturity (the estimated marginal effect is 0.003 statistically significant at 90%). These results, obtained using the continuous variable Maturity years, further support Hypothesis 1: during the growth phase of the industry life-cycle, firms are more likely to engage in product-oriented innovation initiatives; however, as the industry matures, they are more likely to refocus on process-oriented innovation strategies, while reducing their preference for product-oriented innovations. Moreover, the probability of adopting a process-oriented innovation strategy, or dismissing a product-oriented strategy, increases with the time elapsed from the year in which the industry entered the maturity stage. To our knowledge, these findings represent the first firm-level evidence supporting the industry life-cycle theory and the relationship between industry development stages and innovation propensity at firm level. They also provide a crucial benchmark to assess how and to what extent the influence of environmental factors on the firm innovations strategy are moderated by the ownership structure of the company when the industry lifecycle is explicitly considered.

Concerning the control variables, firms' innovation propensity is significantly related to firm size, firm ownership concentration, liquidity ratio, profitability, and industry level of technological innovation (proxied by the High tech industry dummy). More specifically, as indicated by the estimated marginal effects, firm size is positively associated with a larger probability to invest both in product-oriented and process-oriented innovation (all statistically significant at 99%). The coefficients are positive and statistically significant also in the case of patents and organizational innovation. The ownership share of the first shareholder is also found to be positively correlated to the probability of firms investing in innovation initiatives: as ownership concentration increases, firms are more likely to invest in market product innovation, firm product innovation, process innovation and organizational innovation. Firm liquidity is negatively associated to firm innovation propensity: the coefficient of the liquidity ratio is always negative and significant in all innovation models, except in the case of process innovation, where it is negative but not statistically significant. The differential profitability of the firm, instead, correlates positively with firm probability to innovate: companies performing better than their competitors (i.e. companies with higher differential ROS) are 29.2% more likely to invest in market product innovation, 22.9% more likely to engage in firm product innovation, 37.3% more likely to promote process innovation initiatives, and 34.6% more likely to engage in organizational innovations. Finally, firms operating in high-tech industries are found to be more likely to undertake product-oriented innovations (statistically significant at 99% in all models).

### 4.2. *Industry life-cycle, innovation and ownership*

In this section, we test whether the impact of industry life-cycle stages on technological innovation differs for different types of ownership. More specifically, we first investigate whether firm ownership affects the probability of promoting technological innovation by distinguishing product-oriented and process-oriented innovation for the full sample of firms (Table 5). Then, we estimate the same regression on two subsamples of companies experiencing, respectively, the growth and the maturity stage of industry evolution (Table 6). This mechanism

**Table 4**
Industry life-cycle, product-oriented and process-oriented innovation.

| Probit estimations | Mkt product innovation (1) | Firm product innovation (2) | Patent applications (3) | Process innovation (4) | Organizational innovation (5) | Mkt product innovation (6) | Firm product innovation (7) | Patent applications (8) | Process innovation (9) | Organizational innovation (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| Growth | 0.017 | 0.034* | 0.070*** | −0.010 | −0.020 | | | | | |
| | (0.016) | (0.018) | (0.016) | (0.018) | (0.016) | | | | | |
| Maturity years | | | | | | −0.002* | −0.004** | −0.006*** | −0.000 | 0.003* |
| | | | | | | (0.001) | (0.002) | (0.001) | (0.002) | (0.001) |
| Size (Log) | 0.056*** | 0.078*** | 0.092*** | 0.055*** | 0.042*** | 0.055*** | 0.077*** | 0.091*** | 0.055*** | 0.042*** |
| | (0.007) | (0.008) | (0.007) | (0.008) | (0.007) | (0.007) | (0.008) | (0.007) | (0.008) | (0.007) |
| Age (Log) | −0.008 | 0.007 | 0.002 | −0.020* | −0.020** | −0.008 | 0.007 | 0.001 | −0.020* | −0.020** |
| | (0.010) | (0.011) | (0.009) | (0.011) | (0.010) | (0.010) | (0.011) | (0.009) | (0.011) | (0.010) |
| Ownership share | 0.048* | 0.031 | −0.001 | −0.012 | −0.017 | 0.292** | 0.229* | 0.165 | 0.372*** | 0.347*** |
| | (0.025) | (0.027) | (0.022) | (0.027) | (0.025) | (0.117) | (0.130) | (0.107) | (0.130) | (0.118) |
| Liquidity ratio | −0.016** | −0.024*** | −0.014** | −0.005 | −0.018*** | −0.016** | −0.024*** | −0.015** | −0.005 | −0.018*** |
| | (0.007) | (0.008) | (0.007) | (0.008) | (0.007) | (0.007) | (0.008) | (0.007) | (0.008) | (0.007) |
| Diff. ROS | 0.292** | 0.229* | 0.164 | 0.373*** | 0.346*** | 0.048* | 0.031 | −0.001 | −0.012 | −0.017 |
| | (0.117) | (0.130) | (0.107) | (0.130) | (0.118) | (0.025) | (0.027) | (0.022) | (0.027) | (0.025) |
| High tech | 0.119*** | 0.213*** | 0.123*** | 0.003 | −0.006 | 0.119*** | 0.213*** | 0.121*** | 0.003 | −0.006 |
| | (0.038) | (0.037) | (0.037) | (0.038) | (0.035) | (0.038) | (0.037) | (0.037) | (0.038) | (0.035) |
| Observations | 4908 | 4947 | 4900 | 4945 | 4923 | 4908 | 4947 | 4900 | 4945 | 4923 |
| Pseudo R2 | 0.047 | 0.044 | 0.088 | 0.039 | 0.039 | 0.048 | 0.044 | 0.088 | 0.039 | 0.039 |

*Notes:* The table reports marginal effects. Three, two and one star (*) indicate, respectively, a 99, 95 and 90% level of significance. Robust standard errors are in parentheses. All of the variables are defined in Table A1. All regressions include region dummies, not reported for reasons of space.

allows us to understand whether firms' innovation decisions are affected differently by the industry life-cycle stages.

Starting from Table 5, the estimated marginal effects indicate that compared to industrial companies (the reference category), family-owned firms are significantly more likely to invest in innovation activities when the full sample of companies is considered and no distinctions among industry life-cycle stages are made. More specifically, family businesses show a 3.4% increase in the probability of promoting market product innovation (statistically significant at 95%), a 5.3% increase in the case of firm product innovation initiatives (statistically significant at 99%), a 3% increase in the case of new patents (statistically significant at 95%), and 3.3% in the case of process innovation activities (statistically significant at 95%). Conversely, financial controlled companies and state owned enterprises are found not to be statistically different from industrial firms in terms of technological innovation. Despite not providing support to any of the Hypotheses concerning the innovation strategy of financial and state-owned companies (Munari et al., 2010), these findings offer convincing evidence on the role of ownership in the case of family firms during maturity. Consistently with Schmid et al. (2014) and Minetti et al. (2015), we confirm the positive influence of family ownership on technological innovation even using survey data from EFIGE.

Table 6 reports estimation results for the influence of firm ownership on innovation by dealing separately with the growth (columns 1–5) and maturity (columns 6–10) stages of industry evolution. The presented marginal effects confirm that the firm ownership-innovation relationship varies significantly when the industry life-cycle shifts from the growth to the maturity stage, but only for family firms. In particular, we find that while family firms do not present any substantial difference from the baseline during the industry growth, they do come out as very different innovators during maturity, when a product-oriented innovation strategy is far more evident. In detail, for the

**Table 5**
Technological innovation and firm ownership.

| Probit estimations | Mkt product innovation (1) | Firm product innovation (2) | Patent applications (3) | Process innovation (4) | Organizational innovation (5) |
|---|---|---|---|---|---|
| Family firm | 0.034** | 0.053*** | 0.030** | 0.033** | 0.020 |
| | (0.015) | (0.017) | (0.014) | (0.017) | (0.015) |
| Financial | −0.011 | −0.057 | −0.009 | 0.037 | 0.106 |
| | (0.075) | (0.089) | (0.066) | (0.082) | (0.079) |
| State | 0.122 | 0.002 | 0.025 | −0.099 | −0.023 |
| | (0.095) | (0.100) | (0.079) | (0.099) | (0.091) |
| Size (Log) | 0.050*** | 0.073*** | 0.089*** | 0.057*** | 0.043*** |
| | (0.007) | (0.009) | (0.007) | (0.008) | (0.008) |
| Age (Log) | −0.011 | 0.002 | −0.001 | −0.021* | −0.020** |
| | (0.010) | (0.011) | (0.009) | (0.011) | (0.010) |
| Ownership share | 0.038 | 0.029 | −0.016 | −0.024 | −0.022 |
| | (0.025) | (0.028) | (0.023) | (0.028) | (0.026) |
| Liquidity ratio | −0.018** | −0.026*** | −0.013* | −0.003 | −0.018** |
| | (0.007) | (0.008) | (0.007) | (0.008) | (0.007) |
| Diff. ROS | 0.336*** | 0.291** | 0.177 | 0.363*** | 0.348*** |
| | (0.120) | (0.134) | (0.109) | (0.131) | (0.119) |
| High tech | 0.034 | 0.108** | 0.036 | −0.030 | 0.001 |
| | (0.045) | (0.049) | (0.041) | (0.049) | (0.045) |
| Observations | 4864 | 4902 | 4856 | 4900 | 4878 |
| Pseudo R2 | 0.068 | 0.070 | 0.107 | 0.043 | 0.040 |

*Notes:* The table reports marginal effects. Three, two and one star (*) indicate, respectively, a 99, 95 and 90% level of significance. Robust standard errors are in parentheses. All of the variables are defined in Table A1. All regressions include region and industry dummies, not reported for reasons of space.

**Table 6**
Industry life-cycle, technological innovation and firm ownership.

| Probit estimations | Growth | | | | | Maturity | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mkt product innovation | Firm product innovation | Patent applications | Process innovation | Organizational innovation | Mkt product innovation | Firm product innovation | Patent applications | Process innovation | Organizational innovation |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
| Family firm | 0.051 | 0.051 | 0.079** | 0.085** | 0.021 | 0.036** | 0.059*** | 0.024* | 0.031 | 0.024 |
| | (0.038) | (0.041) | (0.036) | (0.040) | (0.035) | (0.017) | (0.019) | (0.015) | (0.019) | (0.017) |
| Financial | −0.075 | 0.174 | −0.065 | −0.026 | −0.067 | 0.028 | −0.071 | 0.004 | 0.067 | 0.139 |
| | (0.131) | (0.159) | (0.140) | (0.170) | (0.124) | (0.093) | (0.104) | (0.080) | (0.097) | (0.095) |
| State | 0.536*** | 0.334 | 0.342 | −0.001 | −0.195** | 0.017 | −0.112 | −0.046 | −0.143 | 0.005 |
| | (0.197) | (0.233) | (0.270) | (0.265) | (0.081) | (0.099) | (0.108) | (0.070) | (0.111) | (0.112) |
| Size (Log) | 0.052*** | 0.093*** | 0.121*** | 0.094*** | 0.073*** | 0.049*** | 0.066*** | 0.089*** | 0.052*** | 0.037*** |
| | (0.019) | (0.021) | (0.019) | (0.020) | (0.017) | (0.008) | (0.010) | (0.007) | (0.010) | (0.009) |
| Age (Log) | 0.000 | 0.022 | 0.002 | −0.055** | −0.032 | −0.013 | −0.001 | −0.005 | −0.018 | −0.015 |
| | (0.025) | (0.028) | (0.025) | (0.027) | (0.023) | (0.011) | (0.012) | (0.010) | (0.012) | (0.011) |
| Ownership share | 0.029 | −0.040 | −0.111* | −0.052 | −0.023 | 0.029 | 0.037 | −0.008 | −0.018 | −0.030 |
| | (0.064) | (0.068) | (0.063) | (0.066) | (0.060) | (0.028) | (0.032) | (0.025) | (0.032) | (0.029) |
| Liquidity ratio | −0.062*** | −0.103*** | −0.045** | −0.027 | −0.045** | −0.013* | −0.016* | −0.010 | 0.001 | −0.016** |
| | (0.022) | (0.023) | (0.021) | (0.022) | (0.020) | (0.008) | (0.009) | (0.007) | (0.008) | (0.008) |
| Diff. ROS | 0.932*** | 1.189*** | 0.467 | 0.200 | 0.357 | 0.253* | 0.156 | 0.130 | 0.387*** | 0.363*** |
| | (0.319) | (0.348) | (0.321) | (0.330) | (0.283) | (0.133) | (0.148) | (0.119) | (0.146) | (0.133) |
| High tech | −0.128 | 0.055 | −0.065 | −0.315*** | −0.050 | 0.048 | 0.114** | 0.067 | −0.009 | 0.004 |
| | (0.117) | (0.174) | (0.123) | (0.093) | (0.140) | (0.048) | (0.052) | (0.045) | (0.052) | (0.048) |
| Observations | 907 | 959 | 899 | 954 | 935 | 3858 | 3888 | 3824 | 3893 | 3869 |
| Pseudo R2 | 0.121 | 0.134 | 0.154 | 0.105 | 0.102 | 0.068 | 0.073 | 0.110 | 0.040 | 0.039 |

*Notes:* The table reports marginal effects. Three, two and one star (*) indicate, respectively, a 99, 95 and 90% level of significance. Robust standard errors are in parentheses. All of the variables are defined in Table A1. All regressions include region and industry dummies, not reported for reasons of space.

subsample of companies operating in growing industries (columns 1–5), the estimated marginal effects of the family firm dummy are not statistically significant, except for the ones related to patent applications and process innovation (0.079 and 0.085, respectively, statistically significant at 95%). By contrast, in the subsample of firms operating in mature industries (columns 6–10), family business is 3.6% more likely to invest in market product innovation (statistically significant at 95%), 5.9% more likely to engage in firm product innovation initiatives (statistically significant at 99%), and 2.4% more likely to apply for new patents (statistically significant at 90%). These findings provide support to Hypothesis 2d. Family ownership does not affect product innovation differently from other owners during the growth stage of industry evolution, but positively affects product-oriented innovation during the maturity phase of the industry life-cycle. These results are consistent with the idea that family firms' investment horizon and survival concerns may foster risky innovation initiatives when the probability of exiting the market is high, as in the maturity phase of industry evolution. In this context, family firm decision makers may see technological innovation, and specifically the risky product-oriented innovation, as a necessary investment to help survival (Zahra, 2005; Gomez-Mejia et al., 2007; Zellweger, 2007; Chrisman and Patel, 2012; Patel and Chrisman, 2014; Thomsen and Pedersen, 2000).

Some statistically significant results have been found for state owned enterprises. When the industry grows (columns 1–5), state owned firms are 53.6% more likely to promote market product innovation (statistically significant at 99%) and 19.5% less likely to invest in organizational innovation (statistically significant at 95%). During the maturity stage of industry evolution, instead, state ownership is found to be not significantly different from industrial companies. State owned enterprises are often set up to strengthen the nation's scientific infrastructure and to foster the production of new knowledge (Munari et al., 2010). This is more likely to occur in those industry sectors at the early stages of development, but strategically relevant for a country. In fact, when the industry enters the maturity stage, homogeneous consumers' preferences, widespread knowledge, and price-based competition reduce state incentives to keep investing in product-oriented technological innovation (Abernathy and Utterback, 1978; Anderson and Tushman, 1990; Cohen and Klepper, 1996; McGahan and Silverman, 2001; Bos et al., 2013). This result only partially supports hypothesis 2c, which predicted a positive effect of state ownership on technological innovation both during the growth and maturity phase of industry evolution. Less indicative findings are found with respect to financial ownership. As reported in columns (1)–(10) of Table 6, firms controlled by financial institutions are not statistically different from industrial companies in terms of innovation activities during both the growth and maturity stages of industry life-cycle.[16] Therefore, we reject both Hypotheses 2a and 2b.

Overall, these results suggest that the impact of the industry life-cycle on technological innovation is significantly affected by the firms' ownership structure, and that the moderating role of the ownership is not trivial and is highly selective when external conditions change significantly, as during the lifecycle shift from growth to maturity.

### 4.3. The role of maturity years

In order to gather additional insights about the joint impact of firm ownership and industry evolution on technological innovation, Table 7 reports the estimation results obtained by interacting our ownership variables with the Growth dummy (Panel A) and the continuous variable Maturity years (Panel B) as a proxy for the intensity of maturity stages of the industry life-cycle. The estimated marginal effects confirm our previous results. First, as reported in Panel A, family owned firms do not behave differently from industrial companies during the growth stage of the industry evolution. Conversely, as presented in Panel B, family ownership positively affects the probability of promoting market-product innovation and firm-product innovation initiatives as

[16] We checked the robustness of these results by also running the basic model separately for each ownership type. The baseline was industrial ownership for all ownership types. We have not included these estimates to save space. Results broadly confirm the findings we obtained in models estimated using the whole set of ownership dummies (Table 6). All results are available from authors upon request.

**Table 7**
Industry life-cycle, technological innovation and firm ownership: Interaction effects.

| Panel A: Growth<br>Probit estimations | Mkt product innovation<br>(1) | Firm product innovation<br>(2) | Patent applications<br>(3) | Process innovation<br>(4) | Organizational innovation<br>(5) |
|---|---|---|---|---|---|
| Family firm * Growth | −0.006 | −0.004 | 0.054 | 0.029 | −0.013 |
| | (0.036) | (0.040) | (0.036) | (0.040) | (0.036) |
| Financial * Growth | −0.109 | 0.072 | −0.095 | −0.136 | −0.122 |
| | (0.134) | (0.197) | (0.102) | (0.166) | (0.120) |
| State * Growth | 0.422** | 0.433*** | 0.236 | 0.253 | −0.033 |
| | (0.213) | (0.127) | (0.261) | (0.230) | (0.209) |
| Growth | 0.016 | 0.028 | 0.028 | −0.029 | −0.005 |
| | (0.031) | (0.034) | (0.030) | (0.034) | (0.031) |
| Family firm | 0.035** | 0.054*** | 0.020 | 0.027 | 0.023 |
| | (0.017) | (0.019) | (0.015) | (0.019) | (0.017) |
| Financial | 0.016 | −0.075 | 0.017 | 0.073 | 0.142 |
| | (0.092) | (0.105) | (0.083) | (0.097) | (0.093) |
| State | 0.023 | −0.118 | −0.031 | −0.155 | −0.015 |
| | (0.100) | (0.110) | (0.075) | (0.107) | (0.105) |
| + *Control Variables* | Yes | Yes | Yes | Yes | Yes |
| Observations | 4864 | 4902 | 4856 | 4900 | 4878 |
| Pseudo R2 | 0.069 | 0.071 | 0.111 | 0.043 | 0.041 |

| Panel B: Maturity years<br>Probit estimations | Mkt product innovation<br>(1) | Firm product innovation<br>(2) | Patent applications<br>(3) | Process innovation<br>(4) | Organizational innovation<br>(5) |
|---|---|---|---|---|---|
| Family firm * Maturity years | 0.010*** | 0.008** | −0.000 | 0.000 | 0.001 |
| | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) |
| Financial * Maturity years | 0.010 | −0.009 | 0.012 | −0.003 | 0.012 |
| | (0.017) | (0.020) | (0.015) | (0.017) | (0.015) |
| State * Maturity years | −0.073*** | −0.116*** | −0.031* | −0.032 | −0.025 |
| | (0.023) | (0.032) | (0.017) | (0.024) | (0.021) |
| Maturity years | −0.007*** | −0.006** | −0.004* | −0.001 | 0.002 |
| | (0.003) | (0.003) | (0.002) | (0.003) | (0.003) |
| Family firm | −0.027 | 0.003 | 0.033 | 0.030 | 0.014 |
| | (0.025) | (0.028) | (0.022) | (0.027) | (0.025) |
| Financial | −0.068 | −0.017 | −0.069 | 0.050 | 0.038 |
| | (0.098) | (0.126) | (0.080) | (0.119) | (0.108) |
| State | 0.472*** | 0.428*** | 0.176 | 0.069 | 0.112 |
| | (0.125) | (0.091) | (0.150) | (0.163) | (0.161) |
| + *Control Variables* | Yes | Yes | Yes | Yes | Yes |
| Observations | 4864 | 4902 | 4856 | 4900 | 4878 |
| Pseudo R2 | 0.071 | 0.073 | 0.110 | 0.043 | 0.041 |

*Notes:* The table reports marginal effects. Three, two and one star (*) indicate, respectively, a 99, 95 and 90% level of significance. Robust standard errors are in parentheses. All of the variables are defined in Table A1. All regressions include control variables, region and industry dummies, not reported for reasons of space.

the maturity stage of industry evolution advances (the interaction term is positive). Second, financial ownership does not affect technological innovation as the industry matures, as suggested by our previous findings. Finally, consistently with previous results, state-owned enterprises are found to reduce product-oriented innovation significantly as the industry enters and advances in the maturity stage (Panel B, columns 1–3).

### 4.4. The role of family management

In order to shed light on the role played by family management, in this section we investigate the differential influence of family ownership and management on family firm innovation behavior over the industry life-cycle. We first estimate the influence of family ownership on innovation by excluding from the estimation sample those family firms run by family CEOs. Then, we contrast the influence of family ownership and family management within the whole sample of family firms, in order to identify the contribution to the innovation profile of the company of the two components of the family governance.

As for the first point, we compare industrial firms, financial companies, state-owned enterprises with only family firms run by external CEOs, thus removing the confounding effect potentially associated with family management and isolating the pure effect of family ownership on innovation. The estimation results reported in Panel A of Table 8 indicate that family firms run by external CEOs are significantly more likely to undertake product-oriented innovation activities during maturity. More specifically, as reported in columns 7–9, family firms with external managers are 5.5% more likely to invest in market product innovation (statistically significant at 90%) than industrial owners, about 7% more likely to engage in firm product innovation initiatives (statistically significant at 95%), and 5.2% more likely to apply for new patents (statistically significant at 90%). These results support our previous findings: when the family-managed firms are excluded from the sample of family firms and companies are evaluated on the basis of their “pure” ownership, family owners are positively and significantly associated with product-oriented innovations during maturity. Therefore, survivor concerns that push family firms to embrace risky product innovation during maturity appear to influence the innovation strategy of the company through a direct ownership effect.

Once the role of family ownership has been checked, we investigate whether family CEOs and professional managers in family firms influence the firm innovation propensity differently during maturity. A potential drawback to this approach concerns the issue of endogeneity: if the firm's characteristics, like its recent performance, are expected to affect the decision on both whether and when to select a CEO from within the family, then the decision to appoint a family CEO may reflect different features at the time of the firm's transition (Demsetz and Villalonga, 2001; Pérez-González, 2006; Adams et al., 2009). To deal with this potential drawback, we adopt a two-stage estimation technique, with a first stage devoted to the estimation of the probability of

**Table 8**
The role of family management.

Panel A: Family firms with external CEOs (Full sample)

| | Growth: Mkt product innovation (1) | Firm product innovation (2) | Patent applications (3) | Process innovation (4) | Organizational innovation (5) | Maturity: Mkt product innovation (7) | Firm product innovation (8) | Patent applications (9) | Process innovation (10) | Organizational innovation (11) |
|---|---|---|---|---|---|---|---|---|---|---|
| Family firm with external CEO | 0.068 | −0.031 | 0.055 | 0.093 | −0.025 | 0.055* | 0.069** | 0.052* | 0.035 | −0.013 |
| | (0.062) | (0.065) | (0.061) | (0.065) | (0.054) | (0.030) | (0.032) | (0.020) | (0.032) | (0.028) |
| Financial | −0.096 | 0.161 | −0.097 | −0.076 | −0.070 | 0.021 | −0.081 | −0.001 | 0.062 | 0.134 |
| | (0.123) | (0.161) | (0.128) | (0.163) | (0.122) | (0.092) | (0.103) | (0.079) | (0.097) | (0.095) |
| State | 0.530*** | 0.334 | 0.334 | −0.008 | −0.197** | 0.003 | −0.129 | −0.052 | −0.152 | 0.005 |
| | (0.198) | (0.234) | (0.265) | (0.262) | (0.080) | (0.097) | (0.108) | (0.068) | (0.109) | (0.112) |
| Observations | 907 | 959 | 899 | 954 | 935 | 3858 | 3888 | 3824 | 3893 | 3869 |
| Pseudo R2 | 0.121 | 0.133 | 0.150 | 0.103 | 0.102 | 0.068 | 0.072 | 0.110 | 0.040 | 0.039 |

Panel B: Family CEOs – Two-step estimates with the probability of appointing a family CEO (Subsample of family firms)

| | 2nd Stage: Growth: Mkt product innovation (1) | Firm product innovation (2) | Patent applications (3) | Process innovation (4) | Organizational innovation (5) | 2nd Stage: Maturity: Mkt product innovation (6) | Firm product innovation (7) | Patent applications (8) | Process innovation (9) | Organizational innovation (10) | 1st Stage: Family CEO (11) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $\widehat{\text{Family}}$ CEO | −0.078 | −0.070 | −0.234** | −0.226** | 0.008 | −0.091* | −0.162*** | −0.057 | −0.148*** | −0.123** | |
| | (0.102) | (0.117) | (0.114) | (0.111) | (0.103) | (0.047) | (0.055) | (0.043) | (0.053) | (0.048) | |
| CEO age | | | | | | | | | | | 0.022*** |
| | | | | | | | | | | | (0.005) |
| Productivity | | | | | | | | | | | −0.001*** |
| | | | | | | | | | | | (0.000) |
| Observations | 581 | 603 | 559 | 596 | 560 | 2512 | 2529 | 2472 | 2506 | 2515 | 3179 |
| Pseudo R2 | 0.126 | 0.123 | 0.157 | 0.122 | 0.118 | 0.073 | 0.076 | 0.110 | 0.044 | 0.043 | 0.158 |

Panel C: Family management. Ratio of family managers on external managers (Subsample of family firms)

| | 2nd Stage: Growth: Mkt product innovation (1) | Firm product innovation (2) | Patent applications (3) | Process innovation (4) | Organizational innovation (5) | 2nd Stage: Maturity: Mkt product innovation (6) | Firm product innovation (7) | Patent applications (8) | Process innovation (9) | Organizational innovation (10) | 1st Stage: Family / Non-family managers (11) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Family / $\widehat{\text{Non}}$−family managers | −0.166 | −0.146 | −0.349** | −0.364** | −0.006 | −0.101 | −0.198** | −0.092 | −0.205** | −0.170** | |
| | (0.155) | (0.181) | (0.176) | (0.171) | (0.158) | (0.071) | (0.083) | (0.065) | (0.081) | (0.073) | |
| CEO age | | | | | | | | | | | 0.080* |
| | | | | | | | | | | | (0.042) |
| Productivity | | | | | | | | | | | −0.004* |
| | | | | | | | | | | | (0.003) |
| Observations | 584 | 612 | 569 | 607 | 572 | 2582 | 2629 | 2543 | 2598 | 2599 | 2739 |
| Pseudo R2 | 0.126 | 0.124 | 0.153 | 0.121 | 0.117 | 0.075 | 0.079 | 0.111 | 0.045 | 0.047 | 0.088 |

Panel D: Family CEOs' experience (Subsample of family firms)

| | 2nd Stage: Growth: Mkt product innovation (1) | Firm product innovation (2) | Patent applications (3) | Process innovation (4) | Organizational innovation (5) | 2nd Stage: Maturity: Mkt product innovation (6) | Firm product innovation (7) | Patent applications (8) | Process innovation (9) | Organizational innovation (10) | 1st Stage: Family CEO (11) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $\widehat{\text{Family}}$ CEO * Foreign experience | −0.027 | −0.044 | −0.027 | 0.124 | 0.008 | 0.049 | 0.118** | 0.066* | 0.055 | 0.073* | |
| | (0.089) | (0.105) | (0.085) | (0.094) | (0.085) | (0.042) | (0.051) | (0.036) | (0.051) | (0.044) | |

(*continued on next page*)

**Table 8** (*continued*)

Panel D: Family CEOs' experience (Subsample of family firms)

| | 2nd Stage: Growth | | | | | 2nd Stage: Maturity | | | | | 1st Stage |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mkt product innovation | Firm product innovation | Patent applications | Process innovation | Organizational innovation | Mkt product innovation | Firm product innovation | Patent applications | Process innovation | Organizational innovation | Family CEO |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) |
| $\widehat{\text{Family CEO}}$ | 0.021 | −0.020 | −0.198* | −0.257** | 0.028 | −0.089* | −0.173*** | −0.053 | −0.147*** | −0.120** | |
| | (0.105) | (0.121) | (0.117) | (0.116) | (0.105) | (0.048) | (0.056) | (0.045) | (0.055) | (0.050) | |
| Foreign experience | 0.415*** | 0.252** | 0.239* | −0.112 | 0.104 | 0.052 | 0.005 | 0.079 | 0.047 | 0.042 | |
| | (0.124) | (0.120) | (0.132) | (0.125) | (0.127) | (0.059) | (0.066) | (0.054) | (0.066) | (0.059) | |
| CEO age | | | | | | | | | | | 0.022*** |
| | | | | | | | | | | | (0.005) |
| Productivity | | | | | | | | | | | −0.001*** |
| | | | | | | | | | | | (0.000) |
| Observations | 581 | 603 | 559 | 596 | 560 | 2505 | 2522 | 2465 | 2499 | 2505 | 3179 |
| Pseudo R2 | 0.141 | 0.137 | 0.172 | 0.124 | 0.123 | 0.080 | 0.085 | 0.128 | 0.049 | 0.051 | 0.158 |

*Notes:* The table reports marginal effects, and regression coefficients in column (11) of Panel C. Three, two and one star (*) indicate, respectively, a 99, 95 and 90% level of significance. Robust standard errors are in parentheses. All of the variables are defined in Table A1. All regressions include control variables, region and industry dummies, not reported for reasons of space.

appointing a family CEO. In running our regressions, we include the full set of control variables described in Section 3.2.4, together with: i) the age of the CEO and i) the firm productivity, as exclusion restrictions. The first variable (CEO age) should be positively associated with the presence of a family manager or a family firm's founder: long-tenured CEOs are more likely to be appointed from within the family group (Cucculelli and Peruzzi, 2017; Coad, 2018), or more likely to pass the company over to another family member. The second one, i.e. the productivity level, should negatively affect the probability of appointing a family CEO. In the case of international markets, Mayer et al. (2014) show that tougher competition in mature markets induces exporters to reduce the set of exported products to only those whose efficiency levels are above the average productivity threshold set by incumbents (Mayer et al., 2014). This may result in a major limitation for family firms, at least for those firms that do not position themselves in the top deciles of the productivity distribution (Bloom and van Reenen, 2007; Bertrand and Schoar, 2007). Furthermore, highly productive firms require managerial abilities that may be scarce or absent in family run businesses because of the limited pool of talents from which family CEOs are selected (Bertrand and Schoar, 2006; Bloom and van Reenen, 2010).

Estimation results are shown in Panel B of Table 8. As marginal effects indicate, family CEOs are less likely to invest in patent applications and process innovation during the growth stage of the industry life-cycle (columns 1–5), whereas they significantly reduce the probability of both process-oriented and product-oriented innovations during maturity (columns 6–10). These findings remain statistically significant when we employ an alternative definition of family management, i.e. the number of family managers on non-family managers in the company (Panel C of Table 8).[17]

In order to test whether these results are driven by the ability gap between family and external managers, in Panel D we introduce a proxy for ability, that is Foreign experience, a dummy variable which is set equal to one if the CEO of the company has worked abroad, and zero otherwise. By interacting this dummy with the presence of family managers in the company (Family CEO), we find that less experienced family CEOs, i.e. those ones without a foreign experience, significantly reduce the probability of introducing product-oriented innovations both during the growth and the maturity stage of industry life-cycle. Conversely, more experienced family managers are positively associated with product, patent, process and organizational innovations during maturity. As a result, if foreign experience is used as a proxy for ability and managerial skills, estimated results show that the lower propensity of family CEOs to invest in risky product innovation almost disappear when the role of professional ability is explicitly taken into account. To sum up, we find that external CEOs in family firms – and family CEOs with foreign experience - show a significant propensity to invest in risky innovation during maturity to offset the risk of exiting the market. By contrast, family CEOs without any significant exposure to foreign professional challenges – our proxy for managerial ability – show a preference towards a more conservative and safe innovation strategy during maturity.[18]

### 4.5. Robustness

We ran some robustness tests on several crucial points: i) alternative methods of allocation of companies to life cycle stages, ii) the influence of different definitions of family ownership, iii) the role of the tenure of the governance structure, i.e. founders vs second and next generations

[17] Both the family management variables are defined using the information provided by the EFIGE survey (see Table A1 in the Appendix for more details about the definition of the variables).

[18] Foreign experience provides significant benefits to the (product and patent) innovation profile of the company during industry growth.

**Table 9**
Allocation of companies by life-cycle stage – Comparison between alternative methods (Hamilton, 1989 and McGahan and Silverman, 2001).

| Stages | Base model (Hamilton) 1995–2013 (# of firms) | McGahan & Silverman 1995–2013 (# of firms) | Number of firms in the same stage (%) | % on base model (3/1) (%) | McGahan & Silverman 1995–2007 (# of firms) | Number of firms in the same stage (%) | % on base model (6/1) (%) |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | |
| Growth | 1798 | 2239 | 1711 | 95.2 | 2011 | 1764 | 98.1 |
| Maturity & decline | 7656 | 8178 | 6663 | 87.0 | 6416 | 5879 | 76.8 |
| Total | 9444 | 10417 | 8374 | 88.7 | 8427 | 7643 | 80.9 |
| % Growth | 0.190 | 0.215 | 0.204 | | 0.239 | 0.231 | |
| % Maturity & decline | 0.811 | 0.785 | 0.796 | | 0.761 | 0.769 | |

*Notes:* Elaborations on EFIGE and Eurostat.

in family firms, and iv) the influence of ownership in sectors that shift back to a renewed growth phase after maturity.

As for the first point, we checked the consistency of the distribution of companies into stages using an alternative procedure to the baseline derived from Hamilton (1989). Following Tavassoli (2015), we computed the allocation of each firm into a growing or mature/declining sector using the procedure of McGahan and Silverman (2001) for two different periods: i) the whole period 1995–2013 and ii) a shorter period that excludes the crisis (1995–2007). Table 9 summarizes aggregate results. Column (1) reports the allocation of companies to stages using the Hamilton model. Based on this method, about 19% of firms operate in growing industries, whereas 81% in mature/declining industries. Using the procedure of McGahan & Silverman (that considers maturity as the first year when the 3-year moving average of the number of firms in the industry is 3pp lower than the value in the previous 3-years – Column 2), the number of firms in growing sectors is larger than in the baseline model, as is also the number of firms in mature sectors. This is due to the less stringent identification method of stages that permits to have a larger number of firms allocated into a wider set of sectors. If we focus on the number of firms allocated into the same stage by the two methods, they range from 87% in case of maturity to 95% in case of growth (Column 4). When the Mc Gahan & Silverman procedure is used on a shorter data set, i.e. 1995–2007 - to exclude the negative influence of the crisis that censors the number of sectors in the growth status - the share of firms allocated into the same stage remains significant (76.8% for mature sectors and 98.1% for growing sectors). In all cases, the choice of the allocation procedure does not seem to affect findings significantly, as we found a very negligible influence of the different allocation methods on estimated results.

To assess the influence of alternative definitions of family firms, Table 10 Panel A reports estimated results using the family ownership share of the controlling family as explanatory variable (continuous). The variable is set equal to zero when the company is not family-owned. Similarly, Panel B reports estimates for the subsample of family firms that excludes industrial holdings from company ownership. In both cases, estimated results do not change in a significant way in comparison to previous results. Additionally, empirical findings remain statistically significant also when financial and state ownership are measured using a continuous variable instead of a dummy variable.

To take into account the overlapping influence of generations and founders of family firms, we matched data on ownership (questions A20 and A21 of the EU-EFIGE survey) with firm age. This procedure permits to distinguish first generation family firms, i.e. those family businesses operating for less than 10 years, and post-founder generation family firms, i.e. family companies established for more than 30 years. Table 11 reports estimated results of the influence of the family ownership on innovation when only founders are considered, i.e. firms younger than 10 years. Founder-run family firms are less active in product innovation than the baseline during growth, whereas they behave like industrial owners during maturity, thus limiting potential biases in the estimates due to sample composition.

As for the reverse industry life cycle, Table 12 includes an estimate of the influence of growth on innovation in these sectors (Panel A) and the impact of ownership on innovation when this reverse life cycle is taken into account (Panel B). From Panel A, new products and patents are more likely to be observed in industries that revert back from maturity to growth: as in the case of nascent industries, the innovation profile of sectors undergoing a significant renewal is mostly characterized by product innovation and patents, whereas process and organizational innovations are rather rare. Concerning the role of ownership (Panel B), there is no significant evidence of owners behaving differently from the industrial ones in those sectors that shift back from maturity to growth. However, both families and the state seem to confirm the innovation pattern already observed in previous results, as they come up as more innovative (respectively, in patents and product new to the market) than industrial owners (baseline). In general, despite the consistency with the main findings, a clear explanation of this evidence would require a deeper analyses that takes into account both the limited number of occurrences (cases) and the puzzling economic scenario that characterizes these sectors.

## 5. Limitations and conclusion

In this paper, we have investigated how firm ownership affects technological innovation over the industry life-cycle. In particular, we first tested whether industry life-cycle stages influence product- and process-oriented innovations. Then, by distinguishing between family businesses, state-owned enterprises, financial controlled companies and industrial firms, we analyzed whether the relationship between industry life-cycle and technological innovation is shaped by the company ownership.

To empirically answer our research questions, we employed very detailed data collected from three main sources: i) a survey on product and process innovations for a large sample of European manufacturing firms (EFIGE dataset), ii) financial data from BvD-Amadeus and iii) industry data on production and number of firms by sector from Eurostat.

The results provide several significant insights for the questions investigated. First, we support one of the most relevant claims of the industry life-cycle theory (Abernathy and Utterback, 1978; Gort and Klepper, 1982; Klepper, 1996): firms focus on product-oriented innovation during the growth stage of the industry life-cycle, and on process-oriented innovation during the maturity phase of industry evolution. Our results confirm the idea that innovative behavior of firms changes significantly over the industry life-cycle and, to the best of our knowledge, this is the first paper that provides direct support by using firm-level data. Moreover, compared to previous studies (Filson, 2001; McGahan and Silverman, 2001; Bos et al., 2013), we employ more detailed information about industry classification (177 sectors at the four-digit NACE level) and firms' innovation initiatives.

Second, we find that industry evolution significantly affects the firm

**Table 10**
Industry life-cycle, technological innovation and firm ownership: Alternative definitions of family firms.

| Panel A: Family ownership shares | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Probit estimations | Growth | | | | | Maturity | | | | |
| | Mkt product innovation | Firm product innovation | Patent applications | Process innovation | Organizational innovation | Mkt product innovation | Firm product innovation | Patent applications | Process innovation | Organizational innovation |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
| Family ownership shares | 0.033 | 0.006 | 0.035 | 0.076 | 0.023 | 0.043** | 0.069*** | 0.030* | 0.021 | 0.011 |
| | (0.047) | (0.051) | (0.045) | (0.049) | (0.042) | (0.021) | (0.024) | (0.019) | (0.023) | (0.021) |
| Financial | −0.083 | 0.165 | −0.084 | −0.041 | −0.067 | 0.028 | −0.073 | −0.001 | 0.059 | 0.129 |
| | (0.130) | (0.161) | (0.135) | (0.167) | (0.125) | (0.094) | (0.104) | (0.079) | (0.097) | (0.095) |
| State | 0.532*** | 0.341 | 0.358 | 0.018 | −0.193** | 0.004 | −0.064 | −0.053 | −0.158 | −0.019 |
| | (0.199) | (0.228) | (0.265) | (0.267) | (0.082) | (0.095) | (0.111) | (0.066) | (0.106) | (0.106) |
| + Control variables | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 910 | 962 | 902 | 957 | 941 | 3861 | 3891 | 3828 | 3899 | 3875 |
| Pseudo R2 | 0.120 | 0.131 | 0.149 | 0.102 | 0.100 | 0.068 | 0.073 | 0.110 | 0.040 | 0.039 |

| Panel B: Family firms excluding industrial holdings | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Probit estimations | Growth | | | | | Maturity | | | | |
| | Mkt product innovation | Firm product innovation | Patent applications | Process innovation | Organizational innovation | Mkt product innovation | Firm product innovation | Patent applications | Process innovation | Organizational innovation |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
| Family firm excluding ind. holdings | 0.079 | 0.049 | 0.028 | 0.072* | −0.006 | 0.036** | 0.056*** | 0.011 | 0.023 | 0.017 |
| | (0.077) | (0.040) | (0.035) | (0.038) | (0.034) | (0.016) | (0.018) | (0.015) | (0.018) | (0.017) |
| Financial | −0.082 | 0.165 | −0.086 | −0.047 | −0.074 | 0.020 | −0.082 | −0.001 | 0.061 | 0.134 |
| | (0.126) | (0.161) | (0.131) | (0.168) | (0.121) | (0.092) | (0.103) | (0.079) | (0.097) | (0.095) |
| State | 0.529*** | 0.328 | 0.328 | −0.027 | −0.196** | 0.010 | −0.121 | −0.049 | −0.147 | 0.002 |
| | (0.203) | (0.238) | (0.269) | (0.264) | (0.081) | (0.098) | (0.107) | (0.069) | (0.110) | (0.112) |
| + *Control variables* | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 907 | 959 | 899 | 954 | 935 | 3858 | 3888 | 3824 | 3893 | 3869 |
| Pseudo R2 | 0.124 | 0.134 | 0.150 | 0.104 | 0.102 | 0.068 | 0.073 | 0.110 | 0.040 | 0.039 |

*Notes:* The table reports marginal effects. Three, two and one star (*) indicate, respectively, a 99, 95 and 90% level of significance. Robust standard errors are in parentheses. All of the variables are defined in Table A1. All regressions include control variables, region and industry dummies, not reported for reasons of space.

**Table 11**
The role of family firms' founders.

| | 2nd Stage: Growth | | | | | 2nd Stage: Maturity | | | | | 1st Stage |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mkt product innovation | Firm product innovation | Patent applications | Process innovation | Organizational innovation | Mkt product innovation | Firm product innovation | Patent applications | Process innovation | Organizational innovation | Founder |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) |
| $\widehat{\text{Founder}}$ | −10.215*** | −7.541*** | −0.208 | −0.780 | 0.228 | −0.019 | −0.195 | 0.119 | −0.094 | −0.005 | |
| | (0.131) | (0.285) | (9.350) | (0.530) | (0.510) | (0.122) | (0.119) | (0.093) | (0.118) | (0.105) | |
| CEO age | | | | | | | | | | | 0.050*** |
| | | | | | | | | | | | (0.019) |
| Productivity | | | | | | | | | | | −0.002** |
| | | | | | | | | | | | (0.001) |
| Observations | 28 | 17 | 38 | 36 | 42 | 210 | 243 | 224 | 228 | 248 | 338 |
| Pseudo R2 | 1 | 1 | 1 | 0.320 | 0.573 | 0.133 | 0.132 | 0.180 | 0.109 | 0.114 | 0.312 |

*Notes:* The table reports marginal effects. Three, two and one star (*) indicate, respectively, a 99, 95 and 90% level of significance. Robust standard errors are in parentheses. All of the variables are defined in Table A1. All regressions include control variables, region and industry dummies, not reported for reasons of space.

**Table 12**
Reverse industry life-cycle.

Panel A: Industry life-cycle, product-oriented and process-oriented innovation

| Probit estimations | Mkt product innovation (1) | Firm product innovation (2) | Patent applications (3) | Process innovation (4) | Organizational innovation (5) |
|---|---|---|---|---|---|
| Growth reverse ILC | 0.057** | 0.067*** | 0.057*** | 0.031 | −0.001 |
| | (0.023) | (0.024) | (0.022) | (0.024) | (0.022) |
| + *Control Variables* | Yes | Yes | Yes | Yes | Yes |
| Observations | 4402 | 4435 | 4386 | 4435 | 4415 |
| Pseudo R2 | 0.046 | 0.044 | 0.089 | 0.039 | 0.037 |

Panel B: Industry life-cycle, technological innovation and firm ownership

| Probit estimations | Growth reverse ILC | | | | |
|---|---|---|---|---|---|
| | Mkt product innovation (1) | Firm product innovation (2) | Patent applications (3) | Process innovation (4) | Organizational innovation (5) |
| Family firm | 0.092 | 0.044 | 0.116** | 0.091 | −0.001 |
| | (0.057) | (0.062) | (0.053) | (0.064) | (0.058) |
| Financial | −0.211 | 0.187 | 0.034 | | 0.076 |
| | (0.136) | (0.202) | (0.308) | | (0.240) |
| State | 0.496** | 0.276 | 0.208 | | −0.181 |
| | (0.210) | (0.240) | (0.412) | | (0.147) |
| + *Control Variables* | Yes | Yes | Yes | Yes | Yes |
| Observations | 434 | 443 | 401 | 421 | 431 |
| Pseudo R2 | 0.156 | 0.134 | 0.164 | 0.154 | 0.132 |

*Notes:* The table reports marginal effects. Three, two and one star (*) indicate, respectively, a 99, 95 and 90% level of significance. Robust standard errors are in parentheses. All of the variables are defined in Table A1. All regressions include control variables, region and industry dummies, not reported for reasons of space.

ownership- innovation link. Despite the extensive literature dealing with the role played by firm ownership and governance on firm innovation decisions, the relationship between ownership and industry dynamics is still a neglected issue. By explicitly considering the industry life-cycle, we find that the firm ownership-technological innovation link varies significantly when the industry shifts from the growth to the maturity stage. In particular, while family ownership does not affect innovation during the growth stage, it positively affects product-oriented innovation during maturity. The main explanation of these results can be found in the peculiar characteristics of family firms and their concerns for survival. While, in normal times, risk averse family owners may prefer a low-risk and safe innovation policy, during maturity they may find it optimal to invest in risky product innovation to make their firms more likely to survive and pass onto future generations. A similar explanation can be found behind the observed stronger resilience of family firms after an industry downturn (Friedman et al., 2003; Villalonga and Amit, 2010), or the preference of family firms to pursue niche strategies related to flexibility or differentiation (such as product innovation initiatives), instead of investment programs targeted to exploit economies of scale (such as process innovation strategies) (Thomsen and Pedersen, 2000).

As for the other ownership types, evidence shows that there are no significant differences in the innovative activity of financial and industrial owners. By contrast, concerns about the future permanence of the company in the industry, and the chance for the family to pass the company to heirs, make family ownership a rather peculiar type of ownership, different from all other ownership types. Also, it is worth adding that some peculiarities emerge when the state as owner is considered, as these firms come out as the most innovative ones during the industry growth. This behavior, which is consistent with the need for the state to assist the development of growth industries, is definitely evident in the case of the most risky innovations, i.e. products new to the market and patents, which require a risk-bearing ability that only the state may probably provide. At the same time, an early disengagement from sectors moving to maturity is the most likely motivation behind the lower probability of introducing patents in mature sectors by state-owned companies.

This study is not exempt from limitations. First, because of the cross-sectional structure of our dataset, causal identification is significantly more difficult than in panel data (Coad et al. 2018). We have tried to mitigate this problem by employing a large set of control variables, but a complete longitudinal studies could provide additional and relevant insights on the issue. Second, our cross-sectional information mainly refers to the 2007–2009 period. Although the analysis was performed on European data and the economic recession had just started in those years, our findings may suffer from the effect of the financial crisis on the industry evolution and the identification of industry lifecycles. Third, as our basic data come from a cross-sectional survey on incumbents, the dataset includes more observations for the maturity stage than the growth stage. Although the focus of the paper is on the innovation behavior during maturity, future research could analyze datasets that have a richer coverage of young and small firms in the growth stage of the industry. Finally, as we analyze industry evolution and technological innovation for a sample of mainly small and medium-sized European enterprises, our results may not be easily extended to other important contexts, such as American or Asian countries, because of major differences in the institutional setting and in the corporate structure of the economic system.

### Declaration of Competing Interest

None.

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### Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.respol.2019.103878.

### Appendix 1. Variable definitions

| Variable | Definition |
|---|---|
| *Innovation measures:* | |
| Market product innovation | A dummy variable equal to one if the firm introduced either a new good or a significantly improved product onto the market before its competitors, and zero otherwise.<br>"*On average in the last three years (2007–2009), did the firm carry out any market innovation (*i.e. *the introduction of a good which is either new or significantly improved with respect to its fundamental characteristics; the innovation should be new to the market)? (i) Yes; (ii) No.*"<br>source: EU-EFIGE survey. |
| Firm product innovation | A dummy variable equal to one if the firm introduced either a new good or a significantly improved product that was already available in the market from its competitors, and zero otherwise.<br>"*On average in the last three years (2007–2009), did the firm carry out any product innovation (*i.e. *the introduction of a good which is either new or significantly improved with respect to its fundamental characteristics; the innovation should be new to your firm)? (i) Yes; (ii) No.*"<br>source: EU-EFIGE survey. |
| Patent applications | A dummy variable equal to one if the firm either applied for a patent, registered an industrial design, registered a trademark or claimed copyright, and zero otherwise.<br>"*On average in the last three years (2007–2009), did the firm…? (i) Apply for a patent; (ii) Register an industrial design; (iii) Register a trademark; (iv) Claim copyright.*"<br>source: EU-EFIGE survey. |
| Process innovation | A dummy variable equal to one if the firm adopted either a new or a significantly improved production technology, and zero otherwise.<br>"*On average in the last three years (2007–2009), did the firm carry out any process innovation (*i.e. *the adoption of a production technology which is either new or significantly improved; the innovation should be new to your firm; your firm does not necessarily have to be the first to introduce this process)? (i) Yes; (ii) No.*"<br>source: EU-EFIGE survey. |
| Organizational Innovation | A dummy variable equal to one if the firm introduced new organizational methods in its business practice, workplace organizations or external relations, and zero otherwise.<br>"*On average in the last three years (2007–2009), did the firm carry out any organizational innovation (*i.e. *the adoption of a new organizational method in your enterprise's business practice, workplace organization or external relations that has not been previously used by your firm)? (i) Yes; (ii) No.*"<br>source: EU-EFIGE survey. |
| *Independent variables:* | |
| Growth | A dummy variable equal to one if in 2007 the industry was in the growth stage, and zero otherwise.<br>source: Authors' elaborations on EUROSTAT data. |
| Maturity years | Number of years from the end of the industry growth phase and the beginning of either the maturity or the decline stage (computed in 2007).<br>source: Authors' elaborations on EUROSTAT data. |
| Family firm | A dummy variable equal to one if the firm is family owned, and zero otherwise.<br>"*Is your firm directly or indirectly controlled by an individual or a family-owned entity? (i) Yes; (ii) No.*"<br>source: EU-EFIGE survey. |
| Financial | A dummy variable equal to one if the firm's main shareholder is a financial institution, and zero otherwise.<br>"*What type is your firm's main shareholder?*"<br>source: EU-EFIGE survey. |
| State | A dummy variable equal to one if the firm's main shareholder is a public entity, and zero otherwise.<br>"*What type is your firm's main shareholder?*"<br>source: EU-EFIGE survey. |
| Industrial | A dummy variable equal to one if the firm's main shareholder is an industrial firm, and zero otherwise.<br>"*What type is your firm's main shareholder?*"<br>source: EU-EFIGE survey. |
| *Control variables:* | |
| Size | Number of employees.<br>source: BvD-AMADEUS. |
| Firm age | Number of years from firm's inception (expressed in logarithm).<br>source: EU-EFIGE survey. |
| Ownership share | Ownership share of the first shareholder.<br>source: EU-EFIGE survey. |

| | |
|---|---|
| Liquidity ratio | A continuous variable computed as current assets over current liabilities.<br>source: BvD-AMADEUS. |
| Diff. ROS | A continuous variable computed as the difference between the firm return on sales and the median return on sales of its industry (at the size class and regional level).<br>source: BvD-AMADEUS. |
| High tech industry | A dummy variable equal to one if the firm operates in a high-tech industry, and zero otherwise.<br>source: BvD-AMADEUS. |
| *Other variables:* | |
| Productivity | A continuous variable equal to value added over number of employees.<br>source: BvD-AMADEUS. |
| CEO Age | Age of the firm's CEO.<br>source: EU-EFIGE survey. |
| CEO Foreign Experience | A dummy variable equal to one if the firm's CEO has a work experience abroad.<br>*"Have any of your executives worked abroad for at least 1 year?"*<br>source: EU-EFIGE survey. |

*Notes:* Balance sheet data refer to 2007.

## Appendix 2. Hamilton's latent state regime switching method

Following Hamilton's (1989) model, we assume that an industry belongs to one of the three latent regimes (growth, maturity, or decline) at any time $t$. The nonstationary time series that characterizes the industry, $\{y_t\}$, is the growth rate of the industry at time $t$, calculated by first differencing the logarithm of industry sales. Based on previous results (Hamilton, 1989; Lahiri and Wang, 1994), a first order autoregressive process for each regime $S(t) \in \{1, 2, 3\}$ can be specified as follows:

$$y_t = \mu_{S(t)} + \phi y_{t-1} + \varepsilon_t \tag{A1}$$

with $\varepsilon_t \sim N(0, \sigma^2)$ and $\mu_1$, $\mu_2$, and $\mu_3$, being the industry growth rates in the three life-cycle stages.

The dynamic of $y_t$ can be easily obtained once we define the probabilities of changes between regimes. In particular, the specification proposed by Hamilton (1989) is a Markovian process of the following form:

$$\Pr(S_t = j \mid S_{t-1} = i,\ S_{t-2} = k,\ \ldots,\ \psi_t) = \Pr(S_t = j \mid S_{t-1} = i) = \rho_{ij} \tag{A2}$$

where $\psi_t$ represents all the past values of $y_t$ prior to time $t$ and $\rho_{11}$, $\rho_{12}$, $\rho_{21}$, $\rho_{22}$, $\rho_{31}$, $\rho_{32}$ are the transitional probabilities associated with regime switches.

Based on the distributional assumptions, the conditional probability is:

$$f(y_t \mid S_t = i,\ \psi_t) = \frac{1}{\sqrt{2\pi}\,\sigma}\exp\left[-\frac{(y_t - \mu_i - \phi y_{t-1})^2}{2\sigma^2}\right] \tag{A3}$$

Then, the joint probability of $y_t$ and $S_t$ is given by the product of conditional and marginal probabilities, that is for the first regime:

$$f(y_t,\ S_t = 1 \mid \psi_t) = f(y_t,\ S_t = 1,\ \psi_t)\Pr(S_t = 1 \mid \psi_t) \tag{A4}$$

The conditional density for an observation at time $t$ is the summation of these joint probability terms over all possible values of $S_t$:

$$f(y_t \mid \psi_t) = \sum_{j=1}^{3} f(y_t,\ S_t = j \mid \psi_t) \tag{A5}$$

The parameters of Eq. (A5) are estimated with a maximum likelihood procedure. The probabilities of being in a certain state given the data observed up to that point in time are instead obtained as a byproduct of an algorithm similar to the Kalman filtering procedure (Karniouchina et al., 2013). In order to reduce the influence of outliers and prevent them from affecting industry stages shifts, we also adopt a full sample smoother to calculate the probability of being in state $j$ (Kim, 1994; Karniouchina et al., 2013).[19] These smoothed probabilities are then used to classify industries into one of the three distinct states. In particular, we calculated these smoothed probabilities for each state/year combination and assigned the industry in that particular year to the industry stage with the highest probability. We then repeat the procedure for each country considered in the analysis.

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[19] Estimation was carried out using the MS_Regress package for MATLAB (Perlin, 2014).

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