High growth episodes among R&D intensive firms:
Evidence for Europe, US and Japan.

Abstract

The purpose of this article is three-fold: first, to test whether inter-industry R&D spillovers are positively associated with the likelihood of experiencing high growth episodes among R&D intensive firms in Europe, US and Japan; second, to explore whether such a relationship is conditional on their level of absorptive capacity (ACAP); third, to assess whether the acquisition of foreign patents (an additional channel to access external knowledge) trigger high growth episodes among a sub-set of R&D intensive firms. For the empirical analysis, we focus on the R&D-intensive manufacturing firms observed between 2002 and 2017 and located in Europe, US and Japan. The empirical findings support the hypotheses suggesting that: inter-industry R&D spillovers are associated with the likelihood of experiencing high growth episodes; absorptive capacity (ACAP) conditions the relationship between inter-industry R&D spillovers and the likelihood of experiencing high growth episodes and shares of foreign patents are positively associated with the likelihood of experiencing high growth episodes among high-tech R&D intensive firms.

Keywords: High growth episodes; Technological proximity; Inter-industry R&D Spillovers; Absorptive capacity (ACAP); Patents.

JEL codes: C41; L25; O33.

1. **Introduction**

Significant attention has been afforded to firm-level high growth episodes to identify the levers that trigger such episodes (Vértesy et al., 2017). Interest in high growth firms (HGFs) was prompted by the observation that they tend to account for the majority of job creation in the US and UK (Anyadike-Danes et al. 2015). However, attention has now moved from the analysis of the structural characteristics of HGFs *per se* towards episodes of high growth that firms can experience, their length[1] and triggers (Coad & Srhoj, 2019; Coad et al., 2018). This article builds on this literature, and more specifically, it focuses on the triggers of high growth episodes among R&D-intensive firms.

R&D-intensive firms are attractive for two reasons. First, they tend to invest routinely in R&D (Monteiro, 2019) and, therefore, experience high growth episodes more frequently than their non-R&D intensive counterparts[2] (Wang & Dass, 2017; Moreno & Coad, 2015). Second, R&D intensive firms have tended to be overlooked with greater attention being placed on other types of firms (Monteiro, 2019)[3]. An essential feature of R&D-intensive firms is that they are often at the centre of innovation ecosystems and therefore, are in a position to benefit from the knowledge produced by several sources, including competitors, suppliers and stakeholders (Liu & Uzunidis, 2016). Consequently, R&D-intensive firms are exposed to external knowledge through R&D spillovers[4] as a result of several mechanisms including, for example, the mobility of workers or horizon scanning exercises (Bloom et al., 2013). In addition, there are cases when firms prefer to engage in open innovation strategies. These include the acquisition of foreign intellectual property (IP) that assist firms to access external knowledge considered unique. They can also complement internal knowledge (Garcia-Muina & Gonzales-Sanchez, 2017) and crucially

[1]Anyadike-Danes et al. (2015) distinguish between high growth episodes and HGFs. They argue that a single episode of high growth is sufficient for a firm to be classified as a high growth firm.

[2] Such a finding results from the link between high growth and innovation (Wang & Dass, 2017).

[3] Traditionally, the literature on high growth has focused on SMEs and knowledge-intensive industries. However, according to Daunfeldt *et al.* (2016), knowledge-intensive industries are more likely to have a higher proportion of HGFs than other types of industries.

[4] This paper will use the terms "R&D spillovers" and "inter-industry R&D spillovers" interchangeably. Here the definition of knowledge spillovers first proposed by Griliches (1979) is used.

cannot be accessed by local competitors, as it is generated in geographically distant locations (Vertesy et al., 2017). Therefore, acquiring foreign IP can be appealing to R&D-intensive firms.

The extant literature suggests that both R&D spillovers and acquisition of foreign IP matter for innovation and business performance (Stefan and Bengtsson, 2017). Theoretically, external knowledge, acquired through R&D spillovers and foreign patents, can be recombined with internal expertise. The recombination process creates the conditions for new products or processes to emerge, contributing to enhanced firm-level performance. However, there exists a gap in the literature as it is not clear whether the recombination process can trigger high growth episodes and what factors facilitate the conversion of external knowledge into firm-level innovation. Two factors have been particularly neglected; first, absorptive capacity (ACAP, henceforth) and the extent to which it contributes to the emergence of high growth episodes; second, the role of technological proximity between the knowledge base of the source and the recipient firms of the R&D spillovers. We seek to address this gap. The purpose of this article is three-fold. First, we test whether inter-industry R&D spillovers are associated with the likelihood of experiencing high growth episodes among R&D intensive firms. Measures of R&D spillovers are weighted by an indicator of technological proximity in line with Bloom et al. (2013). This allows for an appraisal as to whether R&D spillovers from technologically similar industries can carry relevant knowledge to the recipient firm and trigger high growth episodes. Second, we examine whether the relationship between R&D spillovers and high growth episodes is conditional on firm-level ACAP. Finally, we explore whether the share of foreign patents is associated with the likelihood of experiencing high growth episodes among a sub-set of R&D-intensive firms.

Our empirical analysis employs a dataset, sourced from the EU R&D investment scoreboards, of R&D-intensive manufacturing firms observed between 2002 and 2017 and located in three geographical areas: Europe, US and Japan. Episodes of high growth have been identified using the methodology suggested by Esteve-Pérez et al. (2020). We estimate several models where the probability of experiencing at least one high growth episode is regressed against inter-industry R&D spillovers, while accounting for other control variables. The results confirm a positive association between inter-industry R&D spillovers and the likelihood of high growth episodes. In addition, we find that high tech R&D intensive firms can experience high growth episodes through inbound Open Innovation (OI) strategies (Wang & Dass, 2017; Wright & Stigliani, 2012). Furthermore, the relative share of foreign patents can trigger short high growth episodes, while R&D spillovers can trigger extended high growth episodes. Finally, we find that ACAP conditions the relationship between the likelihood of high growth episodes and the R&D spillovers.

The contribution of our research is three-fold. First, it sheds s light on the drivers of high growth episodes among R&D intensive firms. Current literature has neglected the role of R&D spillovers as a trigger of high growth, with authors focusing on the factors, such as access to finance, markets and internal management, that are known to hinder growth. In addition, we highlight the fact that the technological proximity of the knowledge bases of recipient and source firms matters when assessing the relationship between inter-industry R&D spillovers and high growth episodes. Second, we analyse several mechanisms for acquiring external knowledge among R&D intensive firms. In particular, the findings show that acquiring foreign patents affords high-tech R&D intensive firms an additional mechanism to obtain complementary knowledge from international sources. Finally, we assess the importance of the recipient firm's ACAP for inter-industry R&D spillovers to trigger high growth.

The remainder of the article is organised as follows. The following section briefly reviews the background literature and provides the underpinning theoretical framework. The data and empirical methods are described in Section 3, prior to discussing the results in Section 4. Next, the implications of the findings and their limitations are discussed in Section 5. The concluding remarks are offered in Section 6.

2. **Theoretical Background**

2.1 High growth firms vs high growth episodes

Research on the characteristics of HGFs[5] started around two decades ago with the work of Schreyer (2000). While only accounting for a small fraction of the business population, HGFs have attracted much attention because of their propensity to generate new jobs. Indeed, several

[5] The employment-based definition of HGFs, which considers firms with at least ten employees with annual average growth in employment of 20% or more over three years (Eurostat-OECD, 2007), is used.

studies have suggested that, particularly young, HGFs drive employment growth (Anyadike-Danes et al., 2015).

Research has been able to identify some stylised facts about HGFs (Scandura, 2019; Parker et al., 2010). First, they can exist in all industries. HGFs are overrepresented in knowledge-intensive business services (KIBS) and young emerging industries. Second, HGFs are more R&D-intensive than non-HGFs (Monteiro, 2019). Third, HGFs generate knowledge spillovers, benefiting other enterprises through either their geographical proximity (Stefan & Bengtsson, 2017; Wang & Dass, 2017) or membership of industry clusters (Brown, 2011).

Despite progress, what drives high growth remains unclear (Wright & Stigliani, 2012). Research suggests that high growth is not linked to firms' structural characteristics, but instead can be rationalised as a set of episodes (Coad et al., 2014; Du & Bonner, 2017) that can occur several times (Daunfeldt & Halvarsson, 2015). This evidence agrees with existing knowledge on firm growth rates over time (Daunfeldt & Halvarsson, 2015)[6]. The empirical analysis of high growth episodes is a relatively recent phenomenon and while there is some understanding of how episodes evolve, very little is known about their triggers. Gaining a clear understanding of the firm-level factors that have the potential of initiating high growth episodes is relevant to both policymakers and managers (Coad et al., 2014; World Bank, 2019).

2.2 External knowledge and high growth episodes: a theoretical framework

The starting point of our theoretical framework is innovation as a driver of high growth (Savino et al., 2017; Daunfeldt et al., 2016). Considerable scholarly effort has sought to establish a link between innovation and HGFs (Du & Bonner, 2017; Du & Temouri, 2015; Coad & Rao 2008)[7]. The conclusions of these studies reveal that HGFs are more likely to innovate (Du & Bonner, 2017; Coad & Srhoj, 2019; Wang & Dass, 2017) and source knowledge externally than non-HGFs. Product innovations, in particular, have been identified as more important than process

[6] Firm growth as a phenomenon has been often studied from the perspective of the 'Gibrat's Law' (Santarelli et al. 2006). According to this law, the firm growth rate is independent of its size.

[7] Coad & Rao (2008) pointed out that although the literature on innovation and high growth is quite extensive, in reality, there are few robust and consistent results on this relationship. They suggest that this paradox is because several factors that influence the predictability od the innovation process, and hence the capability of firms to successfully innovate.

innovations (Acemoglu et al., 2018) for this purpose. Furthermore, proximity to the technological frontiers matters, with R&D driving high growth among SMEs located in countries closer to the world technology frontier[8].

Given the importance of innovation for high growth, understanding how external knowledge influences innovation is crucial when discussing the relationship between high growth episodes and external knowledge sources such as R&D spillovers. The innovation literature suggests that the production of innovation is a very complex process requiring a variety of inputs (Stefan & Bengtsson, 2017; Wright & Stigliani, 2012). Crucially, knowledge is a key input of the innovation process in line with the resource-based view of a firm (Esteve et al., 2021). New product development can result from the combination of internal expertise with external knowledge (Monteiro, 2019; Messeni Petruzzelli, 2011). This approach to innovation is particularly relevant to SMEs, that rely on access to knowledge via other organisations due to their resource constraints.

Innovators can establish mechanisms to gain access to external knowledge. For instance, firms can imitate knowledge produced by other organisations (Crescenzi & Gagliardi, 2018) such as suppliers, customers and competitors through reverse engineering (Ardito et al., 2019; Di Lorenzo & Almeida, 2017). Alternatively, firms can adopt OI strategies, such as knowledge sourcing, to acquire the IP produced by other firms. However, there are cases where exposure to external knowledge can be involuntary, which appears to be the case of R&D spillovers. Notably, some firms prefer one strategy to acquire external knowledge over the other, and as a result, some heterogeneity among firms in terms of preferences for each strategy can be expected. In the remainder of the section, we explore external knowledge acquisition strategies and the role of ACAP in triggering high growth episodes among R&D-intensive firms (Roberts et al., 2012).

2.2.1 Inter-industry R&D spillovers and high growth episodes

[8] The concept of technological frontier was introduced by Acemoglu et al. (2006) who showed that innovation drives economic growth in countries that are close to the technological frontier.

The arguments regarding the importance of R&D spillovers are well established. R&D investment tends to generate knowledge that can be considered partially equivalent to a public good[9] (Cincera & Veugelers, 2014). Knowledge produced by the investment in R&D can reach firms through some channels such as the scanning efforts of competitors (Giovannetti & Piga, 2017) or the mobility of R&D workers (Fernandes and Ferreira, 2013). Eventually, these spillovers strengthen a recipient firm's internal knowledge base, which can aid innovation in turn (Ibhagui, 2019; Liu and Uzunidis, 2016). Literature, rooted in economics, has emphasised the importance of inter-industry R&D spillovers for business growth (Ibhagui, 2019; Kancs and Siliverstovs, 2016; Lee et al., 2017).

However, involuntary exposure to external knowledge associated with the R&D investment of other firms does not necessarily imply that the recipient firm will benefit from it in terms of enhanced performance or high growth. Firms tend to specialise in specific technological areas. This is because they do not have all the resources internally, whether in terms of skills or complementary knowledge, to exploit the entirety of the external knowledge gained through R&D spillovers. The extent to which knowledge involuntarily acquired through R&D spillovers benefits the recipient firm is dependent on the proximity of the knowledge bases of the source and the recipient firms (Hur, 2017; Bresman et al., 2010). Therefore, R&D spillovers from firms that operate in similar technological areas, can complement existing expertise and lead to innovations that trigger high growth episodes (Ibhagui, 2019; Hur, 2017).

Technological proximity represents the "distance" between the knowledge bases of two firms (Hur, 2017; Bloom et al., 2013). Low technological proximity implies that the recipient firm lacks the capability of recognising useful external knowledge (Nooteboom et al., 2007). In addition, trying to exploit knowledge outside current technological domains can be too costly and create the conditions for diseconomies of scope (Brown, 2011)[10]. As a result, the value of the resulting innovations is low. However, high technological proximity implies that the innovator will have the necessary skills to recognise whether the external knowledge can be exploited. In this case,

[9] Romer (1986) highlighted the importance of knowledge spillovers from R&D investment.

[10] The concept of technological proximity is related to that of ACAP as we explain in more detail in Section 2.2.2.

economies of scope will emerge and translate into higher profits for the innovator (Becker et al., 2020; Rajapathirana & Hui, 2018). Knowledge overlap is a necessary condition to facilitate knowledge exchange between the recipient and the source firms. Empirically, the technological proximity between firms is generally captured by analysing their patents scientific/technological fields (Aldieri et al., 2018; Aldieri & Vinci, 2016; Scandura, 2019); in particular, several authors have used the uncentred correlation index between patent distribution vectors to evaluate technological proximity (Aldieri et al., 2018; Bloom et al., 2013; Cincera, 2005; Orlando, 2004).

Based on these arguments, the exposure to inter-industry R&D spillovers generated by firms technologically close to the recipient firms can generate high-value innovations (Capaldo et al., 2017). In addition, the connection between the exposure to inter-industry R&D spillovers and the production of innovation in the recipient firm suggests that R&D spillovers trigger high growth episodes by stimulating innovation at the firm level. The link among inter-industry R&D spillovers from technologically proximate firms, innovation and high growth episodes is particularly relevant in the case of R&D intensive firms. Such firms tend to specialise in a specific domain and rarely have all the required resources to innovate. Therefore, they are more likely to use external knowledge to develop radical innovations (Coad & Srhoj, 2019; Crescenzi & Gagliardi, 2018). Firms that operate in very technical fields selectively search for knowledge generated by firms in similar fields[11] (Messeni Petruzzelli, 2011), and benefit from technological proximity to the source firms (Ardito et al., 2019).

As investing in R&D is a routine activity for R&D intensive firms, they are more likely to have the internal capability to recognise and exploit the knowledge to which they have been involuntarily exposed (Giovannetti & Piga, 2017). In other words, it would be possible to effectively transform knowledge obtained from R&D (Bloom et al., 2013) and experience high growth episodes as a result. Therefore, it is posited that:

H.1 There exists a positive association between the likelihood of experiencing high growth episodes and inter-industry R&D spillovers (weighted by an indicator of technological proximity) among R&D intensive firms.

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[11] See Messeni Petruzzelli et al. (2007) and Messeni Petruzzelli (2008) for a similar point.

2.2.2 ACAP and high growth episodes

The discussion to this point has highlighted that firms vary in their ability to benefit from the inter-industry R&D spillovers and this ability is dependent on the technology proximity between the recipient and the source firms (Giovannetti and Piga, 2017; Aghion and Jaravel, 2015). Notably, the notion of technological proximity is somehow related to the concept of ACAP, that is, the routines and processes that allow firms to recognise new external knowledge, assimilate it and eventually exploit it[12].

The concept of ACAP is strictly related to the capability of firms to identify external sources of information critical for innovation. Initially, according to Cohen and Levinthal (1990), ACAP was conceptualized an internal capability of the firm shaped by its prior knowledge. Afterwards, Zahra and George (2002) suggested that ACAP is a label for several internal capabilities[13] allowing firms to identify valuable external knowledge and then exploit it for their benefit. So, ACAP, as an organisational capability, is the result of an internal process of knowledge accumulation within the firm. The process of assimilating new knowledge can be protracted, and there exists an element of path-dependence in the sense that firms tend to absorb external knowledge where they have strong absorptive capabilities.

Firms use many strategies to develop their ACAP according to Cohen & Levinthal (1990) who first proposed the concept. However, the literature has highlighted that a firm's ACAP can be maintained and strengthened as a result of its routine activities (such as investment in R&D) that build the internal knowledge base and expertise (Messeni Petruzzelli et al., 2021). Therefore, R&D intensive firms have higher levels of ACAP, associated with the continuous investment in R&D, than other firms in the general population. There are several reasons for this. First, ACAP is path-dependent and cumulative, implying that R&D intensive firms have had the possibility of building their internal R&D capabilities (Zou et al., 2018). Second, R&D-intensive firms have to coordinate complex activities and different technological areas (Ibhagui, 2019; Giovannetti &

[12] The notion of ACAP was first proposed by Cohen & Levinthal (1990).

[13] These capabilities are a) acquisition, b) assimilation, c) transformation, and d) application (Roberts et al., 2012).

Piga, 2017). Possessing ACAP enables firms to develop the skills to identify complementary knowledge and exploit the resulting synergies (Alexander et al., 2018; Talab et al., 2018)[14].

However, adopting annual R&D expenditure as a proxy for ACAP does not consider the fact that firms vary in their capability to convert knowledge into innovations. For these reasons, patents tend to be an alternative indicator of the capability of firms to process technical knowledge. In addition, R&D intensive firms have highly refined learning processes, which allow them to convert knowledge into innovations. For these reasons, it can be argued that R&D intensive firms with a large share of patents exploit external knowledge attached to R&D spillovers.

In terms of high growth episodes, R&D intensive firms with high stocks of R&D and large shares of patents produce high-value innovations, which trigger high growth episodes. Indeed, those firms close to the technology frontier can develop innovations that generate core advances in their technological field. Therefore, the association between the likelihood of experiencing high growth episodes and R&D spillovers is conditional on the level of ACAP among R&D intensive firms. Therefore, it is posited that:

H.2. ACAP (proxied by the firm-level share of patents and its R&D investment) conditions the relationship between inter-industry R&D spillovers and the likelihood of experiencing high growth episodes among R&D intensive firms.

2.2.3 Foreign patents and high growth episodes

Several authors have highlighted the importance of OI strategies when firms want to acquire external knowledge (Weissenberger-Eibl & Hampel, 2021; Chesbrough, 2003). However, OI practices vary across firms (Brunswicker & Van de Vrande 2014; Weissenberger-Eibl & Hampel, 2021). While some firms prefer to engage in strategic alliances, others engage in technology sourcing by acquiring the external IP directly produced by other firms (Garcia-Muina & Gonzales-Sanchez, 2017; Jeppesen & Molin, 2003). There are multiple benefits of knowledge sourcing through the acquisition of IP, such as increased innovation performance and reduced innovation costs. Furthermore, this type of strategy is particularly suitable to SMEs as they prefer to interact

[14] Empirical studies on networking have found that larger firms are engaged in more spatially distant networking relations.

with external organisations to offset their internal lack of capabilities and knowledge (Brunswicker & Van de Vrande 2014). In particular, R&D-intensive SMEs can prefer technology sourcing to other types of open innovation strategies **(**Lee et al., 2017) as this strategy allows to exploit existing synergies among different knowledge bases (Messeni Petruzzelli & Murgia, 2020). Acquisition of foreign patents is a specific technology sourcing strategy (Garcia-Muina and Gonzales-Sanchez, 2017). Firms stand to benefit from the combination of external knowledge produced in different geographies when they are involved in the development of complex innovations (Capaldo, Lavie, & Messeni Petruzzelli, 2017) while searching across different knowledge domains[15]. In particular, the recombination of knowledge from different environments increases the value of the resulting innovation (Savino et al., 2017). Finally, searching geographically distant knowledge allows firms to overcome their organisational bias towards local search (Hur, 2017) while avoiding delays in accessing new technology.

As an OI strategy, acquisition of foreign IP is widespread among firms operating in industries that are R&D-intensive (Schroll & Mild, 2011). There are some good economic reasons for this preference. High-tech firms tend to face global competition and shorter product lifecycles (Coad & Rao, 2008) so they need to launch new products frequently and therefore benefit from deploying OI strategies (Weissenberger-Eibl & Hampel, 2021). Thanks to their networks and the scale of the markets they have access to, firms acquire foreign IP to reduce the risks associated with investing directly into the development of new technologies. In addition, as innovation in high-tech industries tends to be cumulative (Coad & Srhoj, 2019), acquisition of foreign IP allows for the streamlining of the innovation process. As a result, acquisition of foreign patents can trigger high growth episodes among high-tech R&D intensive firms, *ceteris paribus*. Therefore, it is posited that:

H.3. There exists a positive association between the likelihood of experiencing high growth episodes and the firm-level shares of foreign patents among high-tech R&D intensive firms, all other things being equal.

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[15] This concept is close to the concept of "search span" introduced by Capaldo & Messeni Petruzzelli (2014 and 2015) to describe how firms acquire knowledge across different domains.

3.1 Data

The empirical analysis employs the Joint Research Centre-Institute for Prospective Technological Studies (JRC-IPTS) EU R&D investment scoreboards (European Commission, 2017) that collects data on the patents registered by firms (Aldieri & Vinci, 2016). The JRC-IPTS EU R&D investment scoreboards present data from 2002 to 2017. The scoreboards report firm-level data on net sales, annual R&D expenditure, number of employees and annual capital expenditure. In addition, the scoreboards list the industrial sector each firm belongs to, measured at a two-digit level.

Data on patents registered by firms included in the scoreboards is sourced from the database of patents compiled by the OECD between 2002 and 2017 (Maraut et al., 2008). The database we used is REGPAT[16]; it collects data on patents registered with the EU patent office and includes the addresses of the applicant firm and inventors. For our purposes, if the inventor's address is in a different country from the applicant's address, the inventor is labelled as a foreign inventor. In addition, the database records the technical field of each patent and whether the patent holder is an individual or a company. This allows us to match firm-level data sourced from the scoreboards with the data from the OECD REGPAT database (Aldieri & Vinci, 2016).

Monetary values in the scoreboards are expressed in Euros. However, the exchange rate used to convert national currencies into Euros varies each year. To protect against inflationary effects, we convert the data back into its original currency, and then convert the new values into Euros using the exchange rate from 2010 (the reference year). A measure of R&D stock (R&D) using the perpetual inventory method has been computed with a depreciation rate of 0.15, in line with previous studies (Aldieri, 2011). Finally, after applying the cleaning procedure described in Aldieri et al. (2018), the final data-set is a panel of 825 firms observed over 2002-2017.

[16] The OECD database REGPAT reports patent data that have been linked to regions according to the address of the applicants and inventors. Hence the title REGPAT (Regional Patents).

3.2 Variables

3.2.1 Measuring High Growth Episodes

The procedure used by Esteve-Pérez et al. (2020) has been adopted to identify high growth episodes in the sample. Firm size is measured as the annual total turnover[17] and the annual growth rate is calculated as follows:

$$gr_{it} = \ln(SIZE_{it}) - \ln(SIZE_{it-1}) \qquad (1)$$

where SIZE is the firm-level turnover as recorded by the Scoreboards. The annual growth rate (1) allows us to identify the high growth episodes in our sample. A firm is assumed to experience a high growth episode at time t if the growth rate (1) is in the top decile of the sample distribution of growth rates.

In line with the previous literature (Esteve-Pérez et al., 2020), only organic growth episodes are considered for the empirical analysis. Both the three-year moving average of the sample growth rates and a 3-year window have been chosen to reduce the short-term volatility of the variable. This procedure allows for the calculation of a dummy variable HG_{it} taking the value of 1 if the firm has experienced at least one high growth episode at time t, and 0 otherwise. We can also compute the length of each high growth episode. Given that the data is collected annually, the length of a high growth episode is measured as the number of years a firm experiences high growth. For example, an episode starting in 2010 and ending in 2012 is assumed to last three years.

3.2.2 Other independent variables

R&D spillovers are measured by the stock of R&D conducted outside the focal firm. The stock is weighted by a measure of proximal distance between the source and the recipient of the

[17] The literature on high growth has extensively discussed the best proxy of firm size (Coad et al., 2014; Anyadike-Danes et al., 2015; Moreno & Coad, 2015), but it is unclear which one can accurately represent the population of the fast-growth phenomenon (Du & Bonner, 2017).

spillovers (Bloom et al., 2013). Empirical literature distinguishes between knowledge and rent spillovers, and in line with it, we focus on a proxy of 'knowledge' spillovers. The Jaffe measure (1986) computes the uncentered correlation coefficient between the corresponding technology vectors based on patent distribution:

$$P_{ij} = \frac{\sum_{k=1}^{K} T_{ik} T_{jk}}{\sqrt{\sum_{k=1}^{K} T_{ik}^2 \sum_{k=1}^{K} T_{jk}^2}} \qquad (2)$$

where T_i is the technological vector of the firm *i* and P_{ij} is the technological proximity between firm *i* and *j*. So then, the spillovers weighted stock is the following:

$$IS_i = \sum_{i \neq j} P_{ij} K_j \qquad (3)$$

with K_j being the R&D capital stock relative to company *j* (Aldieri et al., 2018). In line with the literature (Di Lorenzo and Almeida, 2017), the firm-level ratio of patents with foreign inventors owned by the firm over its total number of patents is computed as follows:

$$Share\ of\ foreign\ Patents_i = \frac{Number\ of\ Patents\ with\ at\ least\ a\ Foreign\ Inventor_i}{Total\ Number\ of\ Patents_i} / \qquad (4)$$

As for other firm-level characteristics, scholars emphasise size and age as crucial variables in explaining high growth (Esteve-Pérez et al., 2020; Barba Navaretti et al., 2014). For this reason, we sort firms into four groups: Y1 - firms with a level of sales lower than 25th percentile of the sales distribution in year t; Y2 - firms with sales between the 25th and 50th percentile of the sales distribution; Y3 - firms between the 50th and 75th percentile of the sales' distribution and Y4 - firms whose sales level is above the 75th percentile of the sales distribution.

The EU scoreboards report the year the firm was established, and through this variable, the firm's age can be calculated. The variable ranges between 0 and 100 years. Firms less than five years old are classified as very young firms (Age 1), while firms between five and ten years old are classified as young firms (Age 2). Firms between ten and twenty years old are labelled as old firms (Age 3), while firms more than twenty years old are classified as very old (Age 4). This classification is aligned with the literature (Cincera & Veugelers, 2014; Haltiwanger et al., 2013). Both sets of variables are measured at the onset of the high growth episodes. Also, year, region and industry dummies are included.

3.2.3 Descriptive Statistics

The dataset covers 238 high growth episodes over 825 firms across the three regions. An analysis of the high growth episodes by region is reported in Table 1, where the numbers of high growth episodes are shown together with their average length. The table also reports the unconditional probability of experiencing high growth episodes by region. R&D-intensive firms headquartered in the US and Japan are more likely to experience high growth episodes than European firms. Indeed, for the former group, the unconditional probability of experiencing an episode of high growth is equal to 0.11-0.12, while for firms headquartered in Europe, the probability is equal to 0.06. 17% of US, and 15% of EU firms in the sample experienced at least one episode of high growth, while this percentage is 6% in the case of Japanese firms. Moreover, the average length of high growth episodes varies across the regions. On average, an episode of high growth lasts three years for firms in the US but reduces to two years for those firms headquartered in Japan and Europe, a finding consistent with the literature (Bartak et al., 2021; Monteiro, 2019). Additionally, the findings on Japanese and EU firms confirm the episodic nature of the high growth episodes in these regions (World Bank, 2019).

Table 2 lists the average values of the variables by age group. In particular, the variables refer to sales (Y), the number of employees (L), R&D capital stock (R&D), intra-industry spillovers (IS). All variables vary by firm (i), sector (s), country (z) and time (t), with the only exception of the inter-industry R&D spillovers variable that does not vary by firm. Table 2 presents the same statistics for high-tech firms, i.e. firms with R&D intensity larger than 5%. Table 3 presents statistics by geographical area (Europe, US and Japan).

The distribution of firms by age is skewed toward the old and very old firms. Only 60 firms can be classified as very young (the age is less than five years old) and young (the age is between 5 and

10 years old), while the figure goes up to 107 among old firms. Finally, the sample is dominated by very old firms amounting to 658 firms. Firms located in Europe are not very different from those located in the US and Japan in terms of output per capita. However, in terms of R&D intensity, US-based firms outperform other firms in the dataset. Finally, older firms seem to experience longer episodes of high growth than young firms, which might be attributed to their internal capabilities to manage high growth episodes (Mina & Santoleri, 2021).

Regarding the share of foreign patents, while not significant, there exists some difference between the very old firms and the other firms. However, these differences are not marked across the geographical areas under examination. For example, 61% of patents in US firms are foreign, while this percentage goes down to 55% among EU firms.

[Table 1]

[Table 2]

[Table 3]

[Table 4]

Table 4 reports the correlation coefficients among the variables of interest. The correlation coefficient between the total share of patents and the share of foreign patents is very low (0.027), suggesting that multicollinearity is not a problem in this case. The correlation index among R&D expenditure and inter-industry R&D spillovers is above 0.7 but in line with what is found in previous releases of the JRC-IPTS EU R&D investment scoreboard (Aldieri et al., 2018). R&D expenditure correlates positively with the number of employees (correlation index above 0.7), again in line with previous findings (Aldieri et al., 2018). Finally, Figure 1 shows that large shares of foreign patents are concentrated among firms whose high growth episodes are longer than one year.

[Figure 1]

4. Results

4.1 Likelihood of high growth episodes

We examine the probability of experiencing high growth conditional on the previous year's high growth status. We estimate a logit model[18] with random effects, with the standard errors clustered around the firm, where the dependent variable is the dummy variable HG_{it}. Among the regressors, we consider the size and age of the firms, their industry, and the region where they are headquartered. Also, a dummy variable, taking the value of 1 if the firm has experienced high growth in the previous year and 0 otherwise, is added. Finally, the year dummies to control for the possible effects related to the business cycle are added.

The results of this baseline model are presented in Table 5, column 1. As for the other variable, most of the characteristics that matter for high growth (such as age and size) are still crucial to the sample of R&D intensive firms. Firms at the top of the sales distribution are more likely to experience a high growth episode than other firms. Finally, young firms are more likely to experience an episode of high growth, consistent with previous studies (Coad et al., 2018; Du & Temouri, 2015). As for the year and industry dummies, these do not follow a specific pattern[19] and therefore, their coefficients are not shown here.

Next, an expanded specification that contains the variables of interest is explored. The results are shown in Table 5, Column 2. The coefficient associated with the previous year's high growth status is similar to the one found in the parsimonious specification (Column 1). As for the variables of interest, the results confirm that inter-industry R&D spillovers are associated with the likelihood of experiencing an episode of high growth. The marginal effect associated with this variable is estimated. Our results reveal that the probability of experiencing a high growth episode increases by 2.5 percentage points as the inter-industry R&D spillovers increase by one per cent. Figure 2 plots the average marginal effects of the R&D spillovers against the probability of experiencing high growth episodes over the relevant interval of the R&D spillovers in logs, and a positive relationship between the variables can be observed. As for age and size, the results confirm that old firms are less likely to experience one episode of high growth than young firms.

[18] As a robustness test, also the model with a Probit estimator with random effects is estimated. The results from the Logit and the Probit models are very similar.

[19] Bianchini et al. (2017) find that industry dummies do not explain the likelihood of high growth.

In terms of size, the results are in line with those found in the baseline model and the results from World Bank (2019): large firms do experience high growth.
Column 3 presents the results of the same model for the established firms only. Again, the results are in line with those presented in Column 2. So, for this sub-sample of R&D-intensive firms, large firms are more likely to experience high growth episodes, although the coefficient associated with this variable is somehow larger than what one could find when estimating the model for the whole sample of R&D intensive firms. As for the R&D spillovers, these are positively associated with the likelihood of experiencing high growth episodes. Again, the marginal effect is very similar to the one calculated for the whole sample of R&D intensive firms.

[Table 5]

[Figure 2]

4.2 ACAP and high Next we focus attention on ACAP and its role in facilitating the absorption of inter-industry R&D spillovers. We employ measures of ACAP, such as internal investment in R&D, and the total share of patents used. We estimate these models first for the whole sample of R&D intensive firms and then on the subset of established R&D intensive firms.
The results for R&D intensive firms are presented in Table 6. Column 1 shows the model where ACAP is proxied by investment in R&D, while Column 2 reports the estimates of an equivalent model where ACAP is proxied by the total share of patents. The marginal effects associated with the R&D spillovers as well as the interaction term between the inter-industry R&D spillovers and the investment in R&D, calculated at the sample mean, are computed. We find two marginal effects as significant and positive (equal to 0.04 and 0.005, respectively). The sum of the two marginal effects is equal to 0.045, suggesting that the probability of experiencing a high growth episode increases by 4.5 percentage points when the inter-industry R&D spillovers increase by one per cent and the investment in R&D is at the sample average.

[Table 6]

Table 6 presents the results for established R&D intensive firms (Columns 3 and 4). As before, the marginal effects associated with the variables of interest, calculated at the sample mean, is reported. When ACAP is proxied by the internal investment in R&D, the marginal effects of inter-industry spillovers and its interaction with the investment in R&D, computed at the sample mean, are significant, positive and equal to 0.042 and 0.006, respectively. The sum of the two marginal effects is equal to 0.048. The figure suggests that the probability of experiencing a high growth episode increases by about 4.8 percentage points when the inter-industry R&D spillovers increase by one per cent and the investment in R&D is at the sample mean. When the total share of patents proxies the firm-level ACAP, then the probability of experiencing a high growth episode increases by about 7.3 percentage points when the R&D spillovers increase by one per cent and the total share of patents is at the sample average.

4.3 Length of the high growth episodes

Table 7 focuses on the length of the high growth episodes. We compute a new dependent variable taking the value of 1 if the firm has experienced an episode of high growth, which is longer than one year, and 0 otherwise. The estimates show that inter-industry R&D spillovers are still significantly associated with the likelihood of experiencing an episode of high growth (See Table 7, column 1)[20]. The marginal effect is equal to 0.013, implying that the probability of experiencing a "short" high growth episode increases by 1.3 percentage points if the R&D spillovers increase by one per cent. The marginal effect of the share of foreign patents is equal to 0.04 in this specification[21] implying that the probability of experiencing a "short" high growth episode increases by 4 percentage points if foreign patents increase by one per cent.

Table 7, Column 2 also reports the results of a similar model where the dependent variable is now a dummy variable taking the value of 1 if the high growth episode is longer than one year. The marginal effect of the inter-industry R&D spillovers variable is 0.01, like in the previous model. The results are not different from the other model suggesting that the impact of the R&D

[20] The estimates of all other variables are available from the authors upon request.

[21] It is tested whether the interaction term between the share of foreign patents and the R&D spillovers is significant, but it is not.

spillovers on sales growth can last longer than one year. However, in this second specification, the share of foreign patents is not significant[22]. Columns 3 and 4 report the estimates of the equivalent models for the established R&D firms only. The estimates are qualitatively similar to those obtained for the whole sample, although the value of the marginal effects varies. In the case of the share of foreign patents, the marginal effect is equal to 0.06, implying that an increase of one per cent of the share of foreign patents increases the probability of experiencing a short high growth episode by 6 percentage points.

[Table 7]

4.4 High-tech R&D intensive firms and foreign patents

Table 8 focuses on high tech firms defined as firms whose R&D intensity is above 5%. The marginal effect associated with the inter-industry R&D spillovers is equal to 0.03, suggesting that among these firms, for a one per cent increase of the R&D spillovers, the probability that a firm experiences a high growth episode increases by three percentage points. This result is in line with that obtained for the whole sample of R&D-intensive firms. However, in this specific sub-sample of R&D intensive firms (namely the high-tech firms), the share of foreign patents is positively associated with the likelihood of experiencing a high growth episode[23]. The marginal effect size is quite large: it is equal to 0.10, suggesting that a one per cent increase of the share of foreign patents increases by the likelihood of experiencing a high growth episode by 10 percent. The results for the established high-tech firms (Column 2) reflect those found previously, although the marginal effect associated with the share of foreign patents slightly increases for this sub-sample of firms. Overall, these results confirm Hypothesis 3 and are in line with the existing empirical evidence suggesting that acquisition of foreign patents is an important mechanism to

[22] The estimates of a duration model qualitatively confirm these results. However, the exact values of the coefficients (as well as their interpretation) vary. For example, the value of the coefficient associated with the R&D spillovers is equal to 0.54 (short high growth episodes), while it is equal to 0.44 for the second model (long high growth episodes).

[23] However, the interaction term between the share of foreign patents and the R&D spillovers is not significant.

access external knowledge among high-tech firms (Stefan & Bengtsson, 2017; Becker et al., 2020)[24].

[Table 8]

5. Discussion and limitations

5.1 Discussion

The analysis has generated several empirical findings which can shed light on the triggers of high growth episodes among R&D-intensive firms. The starting point in the search for the triggers of high growth episodes is the well-established link between innovation and high growth. Authors have pointed out innovation, in its different shapes, can trigger high growth and have confirmed this relationship in empirical settings (Ibhagui, 2019; Lee et al., 2017). Therefore, the focus is on innovation, which is the output of a process internal to the innovator where internal and external knowledge is recombined. Innovating firms can acquire external knowledge both involuntarily through the exposure to inter-industry R&D spillovers and voluntarily through Open Innovation (OI) strategies. While the literature on innovation management offers a convincing analysis of how firms choose among different strategies for acquiring external knowledge, it is unclear whether these different channels can help trigger high growth episodes. Theoretically, the exposure to inter-industry R&D spillovers can trigger high growth episodes as long as the spillovers originated from industries that are technologically close to those of the recipient firms (Proposition 1). The theoretical analysis has also shown that ACAP can condition the relationship between inter-industry R&D spillovers and high growth episodes (Proposition 2). Finally, the theoretical analysis points out that acquiring foreign IP as an OI strategy can trigger high growth episodes among high-tech R&D intensive firms (Proposition 3).

The empirical analysis supports the propositions, and therefore the results enhance our understanding of high growth in several ways. First, they highlight how the relatedness of technological fields between the source and the recipient of R&D spillovers matters for high

[24] In their study on the US semi-conductor industry, Rosenkopf & Almeida (2003) have studied the relationship between the size of start-ups and the use of formal (alliances) and informal (mobility of personnel and informal geographically mediated networks) mechanisms for knowledge acquisition. They find that the reliance on informal sources of learning decreases with the size of firms, i.e. small firms rely on informal mechanisms of knowledge acquisition, while large firms prefer formal mechanisms.

growth. While the importance of the overlap between two knowledge bases has been highlighted on several occasions by the innovation management literature, our results are quite novel. Second, the results show a connection between technological proximity, R&D spillovers and high growth episodes. The advantage of technological proximity between the source and the recipient firms is obvious: the risks associated with the recombination of different types of technical knowledge decrease together with the informational costs associated with the assessment of external knowledge. Third, consistent with the literature (Messeni Petruzzelli et al., 2021), the research confirms that the level of ACAP affects the ability to identify and absorb relevant external knowledge and, therefore, has a bearing on the firm's likelihood of experiencing high growth episodes. Finally, the empirical analysis suggests that the contribution of external knowledge to the inventive process inside companies is essential for high growth (Scandura, 2019). Typically, firms have been treated as passive recipients of knowledge flows rather than active nodes that want to strengthen the connections with their external environment as well as being selective in the external knowledge they plan to acquire (Zou et al., 2018). On the contrary, our analysis shows that R&D-intensive firms that actively combine ACAP, built through the selection of relevant knowledge, and external knowledge, can experience high growth episodes (Crescenzi & Gagliardi, 2018).

Our analysis shows that the acquisition of foreign patents is an essential component of the innovation strategy of some R&D intensive firms. In other words, some firms use external strategies to acquire external IP (Stefan & Bengtsson, 2017). The analysis shows that this strategy is relevant to R&D-intensive firms that operate in high-tech industries. Indeed, the share of foreign patents is positively and significantly associated with their likelihood of experiencing high growth. While our findings suggest that this is not yet a core strategy for all R&D intensive firms, it is important for high-tech R&D intensive firms. The acquisition of foreign IP is therefore, a viable strategy to acquire external knowledge, a finding that supports the existing practice of recruiting foreign inventors to access specific external knowledge (Becker et al., 2020). Although this possibility has not been explored directly, acquiring foreign IP can offer firms additional advantages. For instance, firms use foreign IP to enter new markets and boost sales through that route (Mina & Santoleri, 2021; Liu & Uzunidis, 2016). Exploring this additional channel through which acquisition of foreign IP may trigger high growth would be an interesting extension of this study.

A further contribution of our study regards the length of the high growth episodes. The analysis shows that the acquisition of foreign patents can trigger only short-term high growth episodes, unlike R&D spillovers. While this result can be rationalised as a key feature of high growth, which can be episodic, it triggers the obvious question of what factors can make an episode of high growth long-lasting. The current research has not explicitly explored the duration of a high growth episode, but one can speculate that some factors can extend the life span of a high growth episode. (Esteve et al., 2021; Haltiwanger et al., 2013). For instance, firms that have acquired foreign IP as part of their overall innovation strategy can have strong expertise in combining different types of knowledge and will experience more sustained high growth than firms that accidentally end up acquiring external IP through the mobility of workers without a clear innovation strategy (Santangelo, 2021; Vahlne & Johanson, 2017). In other words, capabilities of the innovating firm to manage the newly acquired external knowledge can have a bearing on the length of the high growth episode (Rajapathirana & Hui, 2018; Wang & Dass, 2017).

These results generate an additional question for innovating firms: how can they gain exposure to R&D spillovers from firms with overlapping knowledge bases? They could try to develop relationships, such as strategic alliances or other forms of cooperative agreements, with other firms belonging to different innovation ecosystems. However, the search for partners can be costly, and therefore regional policymakers may facilitate such a search process by supporting existing inter-firm networks or clusters where firms from different industries cooperate[25].

[25] Cluster policy (or policy aimed at developing clusters of firms) has been the hallmark of regional economic policy for a very long time. Clusters have been shown to increase local productivity and competitiveness by facilitating the production and dissemination of knowledge as well as the absorption of knowledge spillovers. As a result, firms that belong to clusters benefit from fast productivity growth, which translates into high profits. Unsurprisingly, cluster policy has mostly focused on the development of new clusters and the support of emerging clusters.

5.2 Limitations

As for the limitations of the paper, our analysis has not explored whether, or how, firms target specific technological fields when searching for external IP. Our work does support the notion that firms benefit from knowledge produced in distant geographical contexts, which provides opportunities for different types of recombination. However, further research may be needed to explore to what extent knowledge acquired from foreign contexts needs to be similar to the focal firm's knowledge before it can recombined successfully.

Finally, the analysis has been conducted on R&D-intensive firms. Further research is needed to test whether a OI strategy can benefit other types of firms located in countries characterised by different patenting systems: this new research could enhance the generalisability of the current findings and unearth potential differences among countries.

6. Conclusions

This article has empirically analysed the role of R&D spillovers and the acquisition of foreign patents in triggering episodes of high growth through the analysis of a sample of R&D-intensive manufacturing firms in Europe, US and Japan. Episodes of high growth are not uncommon in the dataset. We find that inter-industry R&D spillovers are associated with the likelihood of experiencing high growth episodes among R&D intensive firms. R&D spillovers also appear to have a bearing on the length of a high growth episode. Moreover, the acquisition of foreign patents can trigger high growth episodes among high-tech R&D intensive firms. Finally, the article confirms the importance of ACAP in triggering high growth episodes among R&D-intensive firms. It is the case that internal R&D expenditure matters in building up the ACAP of R&D intensive firms.

These findings have practical implications for both policymakers and managers. The results matter to managers as they show that innovation can trigger high growth episodes, which affect the firm's long-term prospects (Messeni Petruzzelli et al., 2021). Crucially, the findings suggest that managers can improve innovation management by enhancing the alignment between the domains of their innovation projects and the technological specialisation of their sources of R&D spillovers.

In terms of implications for policy, the analysis supports the notion that high growth episodes can be supported by innovation policies that allow firms to source knowledge externally or outside their organisational boundaries. In this respect, developing innovation ecosystems in industries and regions where technological knowledge overlaps could be the best way to leverage the innovation strategies adopted by firms to trigger high growth episodes. The study has also shown that the acquisition of foreign patents can trigger high growth episodes, and this result highlights the importance of developing favourable trade regimes that support internationalisation.

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Table 1. High Growth episodes statistics by region

	US	JAPAN	EUROPE
Probability of experiencing at least one high growth episode	0.12	0.11	0.06
Total number of high growth episodes	196	111	31
Total number of firms that experience at least one episode of high growth	54	45	14
Average duration of non high growth episodes	4	5	5
Average duration of high growth episodes	3	2	2
Observations	1,635	1,009	487

Note: Authors' calculations based on the EU scoreboards (2002-2017).

Table 2. Descriptive statistics

Variable	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
	Very young and young firms 363 observations (60 firms)		**Old firms 604 observations (107 firms)**		**Very old firms 2,164 observations (658 firms)**		**High-tech firms 1601 observations (457 firms)**	
Y/L	1.01	0.524	0.99	0.500	1.03	1.067	1.03	1.168
R&D/L	0.75	0.320	0.75	0.320	0.78	0.702	0.84	0.776
Inter-industry R&D spillovers/L	0.95	0.444	1.01	0.412	0.80	0.031	1.03	1.169
Share of national patents	0.43	0.160	0.42	0.148	0.40	0.152	0.43	0.157
Share of foreign patents	0.57	0.160	0.58	0.148	0.60	0.152	0.57	0.157
Average length of a high growth episode	<1 year	0.893	2 years	0.452	3 years	1.856	3 years	1.869

Note: Authors' calculations. Variables are measured in millions of EURO PPP 2007. Y/L is the ratio between sales and employees. R&D/L is the ratio between R&D capital and employees.

Table 3. Descriptive statistics by region

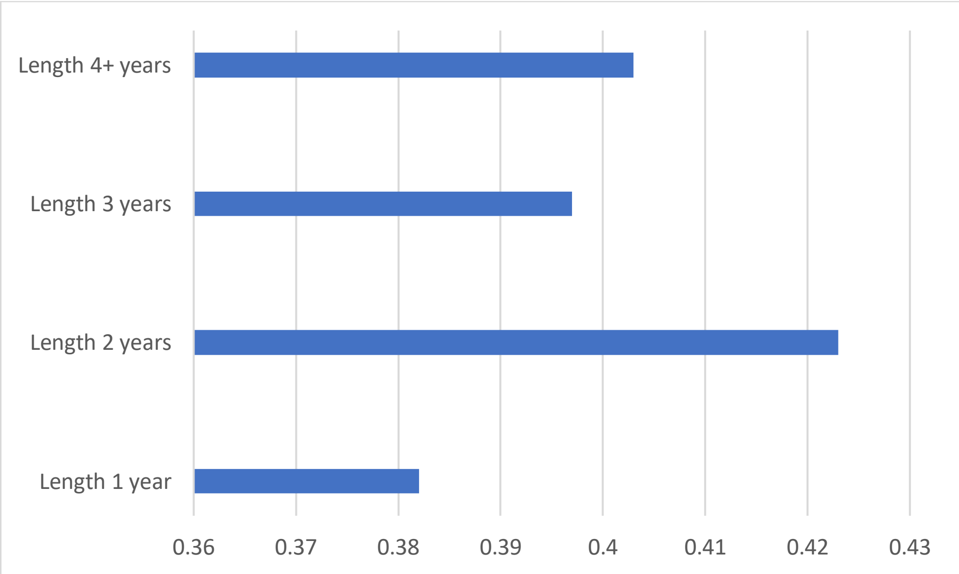
Variable	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
	EU 487 observations (230 firms)		**US 1,635 observations (307 firms)**		**Japan 1,009 observations (288 firms)**	
Y/L	0.99	0.362	1.02	1.167	1.02	0.659
R&D/L	0.77	0.236	0.79	0.777	0.73	0.393
Inter-industry R&D spillovers/L	0.98	0.362	1.02	1.167	1.02	0.659
Share of national patents	0.45	0.171	0.39	0.149	0.41	0.147
Share of foreign patents	0.55	0.171	0.61	0.149	0.59	0.147

Note: Authors' calculations. Variables are measured in millions of EURO PPP 2007. Y/L is the ratio between sales and employees. R&D/L is the ratio between R&D capital and employees.

Table 4. Correlation Matrix

	High growth episode	*Number of employees*	*R&D*	*Inter-industry R&D spillovers*	*Total patents*	*Share of Foreign Patents*
High growth episode	*1*					
Number of employees	*0.091*	*1*				
R&D	*0.049*	*0.741*	*1*			
Inter-industry R&D spillovers	*0.075*	*0.764*	*0.829*	*1*		
Total patents	*0.051*	*0.219*	*0.375*	*0.324*	*1*	
Share of Foreign Patents	*0.027*	*0.003*	*0.031*	*0.012*	*0.027*	*1*

Figure 1. Distribution of Foreign patents by the length of high growth episodes



Note: Authors' calculations.

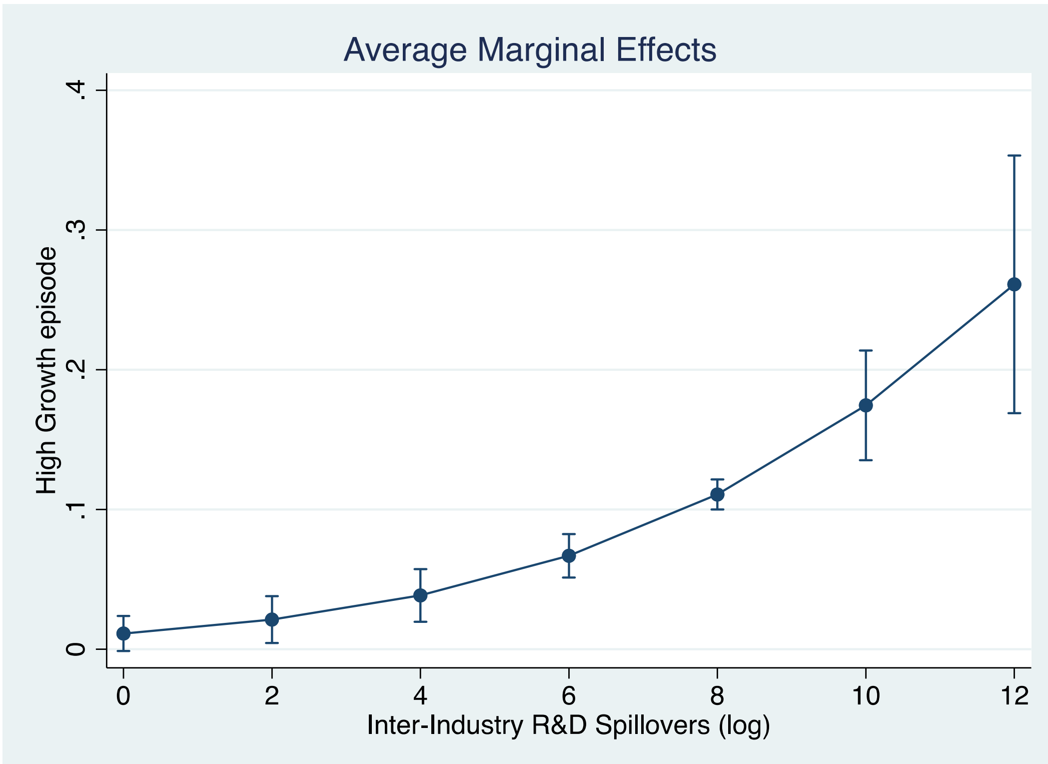
Table 5. Likelihood of experiencing a high growth episode and inter-industry R&D spillovers.

	All regions (All firms)	**All regions (All firms)**	**All regions (Established firms)**
Variables	Marginal effect (Standard error)	Marginal effect (Standard error)	Marginal effect (Standard error)
Has experienced an episode of high growth in the previous year (1/0)	0.056***	0.056***	0.065***
	(0.016)	(0.016)	(0.016)
Y1	0.018	0.019	0.020
	(0.022)	(0.022)	(0.024)
Y2	0.014	0.015	0.015
	(0.015)	(0.015)	(0.016)
Y3	0.007***	0.007***	0.077***
	(0.017)	(0.017)	(0.019)
Age1	0.046*	0.049*	
	(0.028)	(0.028)	
Age2	0.008	0.008	
	(0.019)	(0.019)	
Age3	0.001	0.001	
	(0.013)	(0.013)	
L	0.002	0.002	0.004
	(0.005)	(0.005)	(0.006)

R&D expenditure		0.002	0.004
		(0.008)	(0.009)
Inter-industry R&D spillovers (log)		0.025***	0.026***
		(0.008)	(0.009)
Foreign patents		0.031	0.038
		(0.036)	(0.039)
χ^2	364.32	367.72	329.40
p-value	0.000	0.000	0.000
Year dummies	YES	YES	YES
Region dummies	YES	YES	YES
Industry dummies	YES	YES	YES
N	2881	2881	2768
(No firms)	(825)	(825)	(765)

*Note: *, **, *** marginal effects significant at the 10%, 5%, 1%. Logit estimator with random effects. Standard errors are clustered around the firms. Y4 and Age 4 are the excluded dummy variables. Industry, Region and Year dummies are included in the models. All firms (Columns 1 and 2) and Established firms (Column 3).*

Figure 2. Average marginal effect of R&D spillovers. All firms.



Note: Authors' calculations.

Table 6. Likelihood of experiencing a high growth episode and ACAP.

	All regions (All firms)	**All regions (All firms)**	**All regions (Established firms)**	**All regions (Established firms)**
Variables	Marginal effect (Standard error)	Marginal effect (Standard error)	Marginal effect (Standard error)	Marginal effect (Standard error)
Has experienced an episode of high growth in the previous year (1/0)	0.055***	0.048***	0.063***	0.058***
	(0.016)	(0.015)	(0.016)	(0.016)
Y1	0.019	0.010	0.021	0.010
	(0.026)	(0.023)	(0.028)	(0.024)
Y2	0.006	0.002	0.007	0.009
	(0.017)	(0.015)	(0.018)	(0.016)
Y3	0.032*	0.062***	0.031	0.052***
	(0.020)	(0.018)	(0.022)	(0.019)
Age1	0.055*	0.034		
	(0.029)	(0.028)		

Age2	0.008	0.001		
	(0.019)	(0.019)		
Age3	0.002	0.009		
	(0.013)	(0.013)		
L	0.004	0.001	0.003	0.001
	(0.005)	(0.006)	(0.006)	(0.006)
R&D expenditure	0.046***	0.012	0.047***	0.009
	(0.012)	(0.009)	(0.013)	(0.010)
Inter-industry R&D spillovers (log)	0.040***	0.015*	0.042***	0.015*
	(0.009)	(0.009)	(0.009)	(0.009)
Total patents		0.072***		0.071***
		(0.019)		(0.020)
*Inter-industry R&D spillovers (log) *R&D expenditure*	0.005***		0.006***	
	(0.0011)		(0.011)	
Inter-industry		0.051***		0.058*

*R&D spillovers (log) *Total patents*				
		(0.002)		(0.019)
χ^2	368.72	368.88	325.56	325.05
p-value	(0.000)	(0.000)	(0.000)	(0.000)
Year dummies	YES	YES	YES	YES
Region dummies	YES	YES	YES	YES
Industry dummies	YES	YES	YES	YES
N (No firms)	2881 (825)	2881 (825)	2768 (765)	2768 (765)

*Note: *, **, *** marginal effects significant at the 10%, 5%, 1%. Logit estimator with random effects. Standard errors are clustered around the firms. Y4 and Age 4 are the excluded dummy variables. Industry, Region and Year dummies are included in the models. All firms (Columns 1 and 2) and Established firms (Columns 3 and 4).*

Table 7. Likelihood of experiencing short (up to one year long) and long (longer than one year) episodes of high growth. All regions.

	Probability of a one-year-long high growth episode (All firms)	**Probability of high growth episodes longer than 1 year (All firms)**	**Probability of a one-year-long high growth episode (Established firms)**	**Probability of high growth episodes longer than 1 year (Established firms)**
Variable	Marginal effect (Standard error)	Marginal effect (Standard error)	Marginal effect (Standard error)	Marginal effect (Standard error)
R&D expenditure	0.006 (0.006)	0.002 (0.006)	0.004 (0.006)	0.001 (0.006)
Inter-industry R&D spillovers (log)	0.013** (0.006)	0.010** (0.005)	0.013** (0.006)	0.011** (0.005)
Shares of Foreign Patents	0.045* (0.031)	0.006 (0.022)	0.061* (0.033)	0.004 (0.024)
Year dummies	YES	YES	YES	YES
Region dummies	YES	YES	YES	YES
Industry dummies	YES	YES	YES	YES
χ^2 (p-value)	204.47 (0.000)	471.27 (0.000)	186.28 (0.000)	430.44 (0.000)

*Note: *, ** marginal effects significant at the 10%, 5%. Logit command. Y4 and Age 4 are the excluded dummy variables. Industry, Year and Region dummies are included in the models.*

Table 8. Likelihood of experiencing a high growth episode. High-tech firms.

	All regions High tech firms (All firms)	**All regions High tech firms (Established firms)**
Variables	Marginal effect (Standard error)	Marginal effect (Standard error)
Has experienced an episode of high growth in the previous year (1/0)	0.096***	0.108***
	(0.021)	(0.022)
Y1	0.019	0.026
	(0.032)	(0.034)
Y2	0.011	0.021
	(0.025)	(0.027)
Y3	0.009***	0.092***
	(0.026)	(0.028)
Age1	0.015***	
	(0.057)	
Age2	0.002	
	(0.030)	
Age3	0.017	
	(0.020)	
L	0.006	0.006
	(0.007)	(0.008)
R&D expenditure	0.001	0.002

	(0.012)	(0.013)
Inter-industry R&D spillovers (log)	0.035***	0.036***
	(0.013)	(0.014)
Foreign patents	0.102**	0.110**
	(0.054)	(0.056)
χ^2	215.13	195.61
p-value	0.000	0.000
Year dummies	YES	YES
Region dummies	YES	YES
Industry dummies	YES	YES
N	1601	1238
(No firms)	(457)	(397)

*Note: *, **, *** marginal effects significant at the 10%, 5%, 1%. Logit estimator with random effects (marginal effects). Standard errors are clustered around the firms. Y4 and Age 4 are the excluded dummy variables. Industry, Region and Year dummies are included in the models.*