Are High-Growth Firms Overrepresented in High-tech Industries?

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Abstract: It is frequently argued that policymakers should target high-tech firms, i.e., firms with high R&D intensity, because such firms are considered more innovative and therefore potential fast-growers. This argument relies on the assumption that the association among high-tech status, innovativeness and growth is actually positive. We examine this assumption by studying the industry distribution of high-growth firms (HGFs) across all 4-digit NACE industries, using data covering all limited liability firms in Sweden during the period 1997–2008. The results of fractional logit regressions indicate that industries with high R&D intensity, ceteris paribus, can be expected to have a lower share of HGFs than can industries with lower R&D intensity. The findings cast doubt on the wisdom of targeting R&D industries or subsidizing R&D to promote firm growth. In contrast, we find that HGFs are overrepresented in knowledge-intensive service industries, i.e., service industries with a high share of human capital.

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1. Introduction

Most firms grow slowly or not at all, while a small number of high-growth firms (HGFs) are major drivers of net job creation and economic growth (Birch and Medoff, 1994; Storey, 1994; Henrekson and Johansson, 2010; Hölzl, 2010; Coad et al., 2014a). HGFs have therefore received increasing attention from policymakers and researchers in recent years.

The European Commission (2010) mentions support for high-growth SMEs as a political objective in its Europe 2020 strategy, highlighting the share of fast-growing, innovative firms as a key indicator to measure the strategy's progress. Researchers also argue that policymakers should cease supporting start-ups and instead focus on the more promising potential entrepreneurs (Vivarelli, 2013: 1479).

For example, Shane (2009) states that because most start-ups have no growth ambitions and a large majority of them will not survive, policy should instead target HGFs. However, as Mason and Brown (2013) note, the only practical policy advice Shane provides on how to achieve this object is to extend existing schemes that provide financial incentives for small firms to undertake R&D, e.g., R&D tax credits. Furthermore, the more general concern that firms may be underinvesting in R&D has resulted in government policies such as favorable fiscal treatment and R&D subsidies (Coad and Rao, 2010). OECD (2010), for example, reports that most policy initiatives implemented across its member countries rely on facilitating access to finance and support for R&D and innovation.

Many policies for promoting growth in general and among HGFs in particular are, in other words, strongly biased towards high-technology sectors, typically defined as industries with a high degree of R&D intensity (Eurostat, 2012; see also Schneider and Veugelers, 2010; Coad et al., 2014a). As noted by Mason and Brown (2013: 214), "this clearly indicates that policy-makers view high-technology sectors as the main generators of potential HGFs". Whether HGFs have a higher presence in high-tech industries is thus important from a public policy perspective.

Nonetheless, it has been noted that HGFs are not necessarily synonymous with high-tech firms (Brännback et al., 2010), and at present, there is little evidence that HGFs are more common in such industries. Rather, a number of studies, addressing different countries and time periods, suggest that HGFs exist in most industries and are not overrepresented in high-technology sectors (Henrekson and Johansson, 2010).

As Bleda et al. (2013: 115) note, "there is little evidence that the [high-tech] sector has a large impact on the emergence of gazelles". For example, HGFs are nearly equally present in high-tech and low-tech sectors in the UK (Nesta, 2009), where only approximately 15 percent of HGFs operate in high-tech sectors. Furthermore, these firms do not necessarily have extensive R&D or patent activity (Mason and Brown, 2012). If anything, when considering a variety of countries, there appear to be more HGFs in service industries relative to other sectors such as manufacturing (Henrekson and Johansson, 2010).

In the words of Buss (2002: 18), "policy makers chase high-tech firms as a priority when other sectors might pose better opportunities". For this reason, Mason and Brown (2013) argue that government policies to promote HGFs focus too narrowly on high-technology industries and should be re-directed to also include other industries (see also Brown et al., 2014).

Their advice is however based on studies that generally consider a limited number of industries, apply restrictive firm size thresholds, and use a high level of industry aggregation. Thus, the question of whether HGFs are overrepresented in high-technology industries – or elsewhere – has yet to be satisfactory answered.

In this paper, we argue that on the basis of what is generally known about the tails of the firm growth rate distribution, where HGFs reside, there is little reason to believe that there should be a positive association between R&D intensity and growth. In fact, previous evidence suggests that the crucial factor that seems to explain the prevalence of fat tails in the growth rate distribution is not R&D, but rather some measure of human capital, e.g., special skills and training (Rossi-Hansberg and Wright, 2007; Klette and Kortum, 2004).

The purpose of this paper is to examine this question empirically by testing three hypotheses concerning the industry distribution of HGFs. The first two hypotheses are formulated to assess the conventional wisdom that HGFs are overrepresented in R&D-intensive or high-tech industries. The third hypothesis stipulates that HGFs are more prevalent in service industries with a high level of human capital, a question that has been to some extent overlooked in the previous HGF literature.

Using a fractional logit model suitable for proportions that can take limiting values, we test these hypotheses using a data set that represents all limited liability firms in Sweden during the period 1997–2008. We define HGFs as the one percent of firms in the economy that experienced the fastest (absolute or relative) employment or sales growth during a 3-year period and use the share of HGFs in industries at the 4-digit NACE-level as the dependent variable.

Concerning the first hypothesis, we find little evidence that higher industry R&D intensity is associated with a greater share of HGFs, regardless of how HGFs are defined. Instead, higher R&D intensity typically implies a smaller share of HGFs in the industry considered. The results are more ambiguous when considering industries defined as high-tech (i.e., R&D-intensive) manufacturing industries by Eurostat because the effect can go both ways, and it is difficult to observe any consistent pattern. These findings challenge the prevailing view among policymakers that high-tech or R&D-intensive industries are beneficial for the emergence of HGFs. In contrast, we find some support for our third hypothesis, in that service industries characterized by a high share of tertiary educated workers are likely to experience a greater share of HGFs than the average industry. This suggests that further research should shine a light on the importance for human capital in fostering HGFs.

All results remain qualitatively similar when we perform regressions at the 3- and 5-digit NACE-levels, distinguish between organic and acquired growth, and only consider industries with at least 30 or 100 employees, as robustness checks. .

The remainder of the paper is organized as follows: A theoretical background on the relationship between innovation activities and firm growth is presented in Section 2, together with an overview of previous studies on the industry distribution of HGFs, before we formulate our hypotheses. Data and descriptive statistics regarding the industry distribution of HGFs are described in Section 3, while the econometric model is presented in Section 4 and the results in Section 5. Concluding remarks are provided in Section 6.

2. Innovation activities, firm growth, and HGFs

The Austrian economist Joseph Schumpeter (1934, 1943) ascribed economic growth to creative destruction – the process of transformation that accompanies innovation, caused by the discovery and use of novel ideas. From a Schumpeterian perspective, the innovations introduced by firms represent new knowledge, the economic value of which is not known with perfect certainty. Innovations can therefore be considered business experiments subject to a market test. In the market, firms are established to exploit and commercialize these ideas. But what firms? Schumpeter gave several answers to the question during his academic career.

The early "Mark I" Schumpeter (1934) emphasized entrepreneurship and the role of new (small) ventures in introducing novel ideas into the economic system. Subsequently, "Mark II" Schumpeter (1943) would argue that innovation was a routinized process best performed by large (old) firms, which are able to reap the benefits of economies of scale in production and R&D (Malerba and Orsenigo, 1995). Associating innovation with high-tech sectors and R&D can hence be regarded as ascribing to “Mark II” Schumpeter’s view of the world. As Audretsch et al (2006) point out, innovative activities are usually seen as the result of systematic and purposeful efforts to create new knowledge by investing in R&D, followed by commercialization (Griliches, 1979; Chandler, 1990; Cohen and Levinthal, 1989; Warsh, 2006).

The questions of which firms innovate and whether the same firms grow have caused a longstanding discussion (Davidsson et al., 2010). While “a propensity for innovation emerges in general as a firm’s growth driver” according to Vivarelli (2013), others stress that the self-reinforcing dynamics in the economy may lead to a relatively weak association between the ability to innovate and actual performance, and even if firms are successful in innovation and benefit from it, it is not clear that they will grow (Kirchoff, 1994; Geroski et al., 1997; Coad and Hölzl, 2010; Denrell and Liu, 2012; Coad et al., 2014b:8).

The Mark I – Mark II dichotomy can be related to the literature on ‘technological regimes’ pioneered by Winter (1984), which argues that the industry-specific technological regime has a major influence on firm competitiveness (Audretsch, 1995). Audretsch and Thurik (2000) argue that in recent decades, highly developed economies experienced a general shift from a managed to an entrepreneurial economy, and van Stel et al. (2005) relate Mark I and II innovation to an ‘entrepreneurial’ and a ‘managed’ economy, respectively. While knowledge-driven innovation is frequently thought of as the outcome of R&D-activities, a set of other means of innovation, such as learning-by-doing, networking and combinatorial insights, suggests a role for entrepreneurs (Braunerhjelm 2011). The production of new products or qualities can hence occur due to either R&D investments by incumbents, or by entrepreneurial start-ups who combine knowledge in innovative ways without R&D (Acs et al., 2009).

If there has indeed been a shift towards Mark I innovation in recent decades, then this presents a conundrum for policymakers focusing on high-tech industry, as Mark I-innovation is not as readily associated with high-tech industries as Mark II-innovations. However, this shift is arguably a matter of degree, and many studies emphasize the complementary roles of firms of different sizes. While large, established firms succeed in traditional technological fields based on large R&D activities, the function of new firms is to explore new technological areas. Small, entrepreneurial firms introduce many of the radically new innovations, 'revolutionary breakthroughs', while large firms are more risk-averse and provide 'cumulative incremental improvements', the combined effect of which should not be underestimated (Acs and Audretsch, 2005). As Baumol (2004: 13) writes, "Of course, that initial invention was an indispensable necessity for all of the later improvements. However, it is only the combined work of the two together that made possible the powerful and inexpensive apparatus that serves us so effectively today".

Nonetheless, many theoretical models have associated R&D with innovation and firm growth, thereby implicitly subscribing to a Mark II view of the world.[1] For example, Pakes and Ericson (1998) describe firm growth as a process of "active learning", in a model in which firms maximize expected net cash flows and are aware of productivity distribution shocks (see also Hopenhayn, 1992; Ericson and Pakes, 1995). Contrary to Jovanovic's (1982) model of passive learning, Pakes and Ericson (1998) highlight the importance of learning by undertaking innovative activities, in that a firm must decide how much to invest in R&D. Klette and Griliches (2000), however, construct a quality ladder model to incorporate firm growth and R&D, such that firms compete to improve the quality of products through cumulative innovations by investing in R&D, which is treated as a sunk cost.

However, while a Mark II view of the word has theoretical traction, the empirical picture is far from clear-cut, which Coad and Rao (2008) consider a paradox. While many theoretical and descriptive contributions highlight the importance of innovation in firm growth, few studies observe a strong association between innovation and firm growth. This may be because converting R&D into innovation and innovation into growth takes time (Coad and Rao, 2008), an observation that is further complicated by the uncertainty inherent in any innovative process (Cefis and Orsenigo, 2001; Coad and Rao, 2010; Segarra and Teruel, 2014).

There are also models that provide the opposite indication, at least with

[1] This is also the case for endogenous growth models (c.f. Romer, 1986, 1990; Lucas 1988; Rebelo, 1991; Aghion and Howitt, 1992; Segerstrom, 1995) in which the importance of knowledge spillovers is emphasized. Such models predominantly regard the growth process as an R&D race in which a fraction of R&D translates into successful innovations. Thus, while "the new growth theory is a step forward in our understanding of the growth process, the essence of the Schumpeterian entrepreneur is missed" (Acs 2009; 328). Attempts to introduce Schumpeterian entrepreneurs, who innovate but are not involved in R&D activities, have been made by, e.g., Acs et al. (2004, 2009) and Braunerhjelm et al. (2010).

respect to R&D and growth. Building on previous literature (cf. Pakes and Ericsson, 1998; Klette and Griliches, 2000), Klette and Kortum (2004: 1007) identify two opposing forces that should influence the empirical relationship between R&D and firm size. On the one hand, there are diminishing returns to additional R&D investments. On the other hand, large firms have more knowledge resources that they can devote to R&D activities. The empirical evidence suggests that these two forces cancel one another out on average, making R&D intensity (i.e., R&D expenditures as a fraction of revenue) independent of firm size (see also Cohen and Klepper, 1996).

This also entails that large firms have higher R&D expenditures. Moreover, it is well established that the standard deviation of firm growth is smaller for large firms than for small firms (Stanley et al., 1996). Because a higher standard deviation entails thicker tails, one would hence expect a negative relationship between R&D-expenditures and the industry proportion of HGFs. Considering R&D-intensity (expenditures/revenue) or controlling for industry size would then lead to a prediction of no relationship between R&D and firm growth, provided that the two forces cancel one another out. Thus, from the perspective of the firm growth rate distribution, the link between R&D and high growth seems tenuous at best.

Therefore, it is perhaps not surprising that previous empirical studies on the industry distribution of HGFs paint a rather ambiguous picture. Early research found evidence of a link between technology and firm growth (Storey, 1991, 1994; Kirchoff, 1994), and a number of more recent studies have found indications of a positive association between high-tech status or R&D intensity and HGFs (Schreyer, 2000; Delmar et al., 2003; Hölzl 2009; Stam and Wennberg, 2009). Schreyer (2000: 25), in a study covering six European countries, notes that "all the existing evidence points in the same direction: high-growth firms are more technology intensive than the average firm." Hölzl (2009), moreover, finds that in countries closer to the technological frontier, HGFs have a higher R&D intensity than non-HGFs. Further, in a least squares regression framework, Stam and Wennberg (2009) demonstrate that R&D has a positive effect on growth for the top 10 percent of fastest growing startups, but this is not the case for the overall population of firms. In a study of Spanish firms, Segarra and Teruel (2014) find that R&D investments positively affect the probability of becoming a HGF but the effect is greater and more often significant in manufacturing industries than in service industries.

Nevertheless, other studies report either an absence of or a negative link between high-tech status or R&D and the presence of HGFs (Birch and Medoff, 1994; Birch et al., 1995; Almus, 2002; Acs et al., 2008; Wyrwich, 2010; Nesta, 2009). It has become something of a "stylized fact" (Henrekson and Johansson, 2010) that HGFs can be found in all industries (Deschryvere, 2008; Léopez-Garcia and Puente, 2009; Anyadike-Danes et al., 2009; Nesta, 2009; Mason and Brown, 2012) and, if anything, are overrepresented in service sectors (Autio et al., 2000; Schreyer, 2000; Halabisky et al., 2006).

Some studies furthermore indicate that HGFs are overrepresented in knowledge-intensive service industries, i.e., service sectors characterized by a high level of human capital (Delmar et al., 2003; Davidsson and Delmar, 2006; Deschryvere, 2008). While this is by no means a universal finding, it receives credence from the literature on the firm growth rate distribution. Notably, Rossi-Hansberg and Wright (2007) demonstrate that high growth rates and a higher standard deviation are related to the amount of human capital specific to the industry, e.g., special skills and training. These characteristics are also more present in service industries than in capital-intensive industries, which is consistent with the assessment of a possible overrepresentation of HGFs in service industries (Henrekson and Johansson, 2010). Generally, the importance of education and human capital in fostering firm entry, survival and growth has been demonstrated in a number of studies (Bates 1990; Gimeno et al., 1997; Acs et al., 2007; Geroski et al., 2010; Colombo and Grilli, 2010; Arivantis and Stucki, 2012).

Granted, the ambiguity in the previous HGF literature is in part to be expected given the ever-changing nature of the economy. As Dosi (2007) argues, heterogeneity in degrees of innovativeness and production efficiencies and, hence, firm growth should be expected to be the outcome of idiosyncratic capabilities, mistake-ridden learning and forms of path-dependent adaptation. Nonetheless, it is possible to identify certain factors that may help explain the ambiguous findings reported in previous research.

First, as discussed above, conditions may differ across countries and over time, and studies address different countries and time periods, often cover only a limited number of industries, and apply size thresholds. Furthermore, because their industry distribution is only one of many aspects of the HGFs under examination, little space is generally devoted to this issue; however, in recent years, some studies (Almus, 2002; de Wit and Timmermans, 2008; Hölzl, 2009; Wyrwich, 2010; Stam and Wennberg, 2009; Segarra and Teruel, 2014) employ econometric methods to examine it directly.

As demonstrated above, the Mark II definition of innovation is closely tied to R&D. Indeed, while firms perform R&D activities with a variety of objectives in mind, most business R&D seeks to develop new and improved goods, services, and processes (NSF, 2010: 18), activities that overlap with several of the categories that Schumpeter lists as instances of innovation (Schumpeter, 1934: 66). Considering the previous empirical literature considering the link between R&D and growth, however, lends little support to the notion that additional R&D would translate into higher growth rates.

Notably, the work of Klette and Kortum (2004) and Rossi-Hansberg and Wright (2007) may in part explain why the previous evidence on the industry distribution of HGFs is so ambiguous with respect to their presence in high-tech industries and stands in stark contrast to the prevailing view among policymakers that the relationship between R&D intensity and high growth is a positive one.

In view of the importance of high-tech status as a tool that policymakers employ to identify HGFs, empirical studies that explicitly examine the association among high-tech status, innovation and HGFs are needed. This makes it relevant to formulate and test the two hypotheses regarding the relationship between industry R&D intensity and the industry distribution of HGFs. These hypotheses are hence formulated in view of their importance for policy and are not theory-driven.

Hypothesis 1: *Ceteris paribus, HGFs will be more common in industries with greater R&D intensity.*

If current policies targeting high-tech industry to promote high-growth firms are sound, then one would expect us to be unable to reject this hypothesis. In view of the previous literature concerning the link between R&D and growth, we however expect a non-existent relationship.

The second hypothesis is formulated with a particular definition of high-tech industries in mind, namely that espoused by OECD/Eurostat, which defines industries as high-tech manufacturing industries according to their global technological intensity[2]. Scrutinizing how this particular definition

[2] In the OECD International Standard Industrial Classification, technology intensity is measured through two main indicators: R&D divided by production and R&D divided by value added. In its own words: "The Secretariat experimented with various criteria to identify the technology content of an industry, but quantification was hampered by the absence of data. As a result, R&D intensity became the sole criterion" (Hatzichronoglou, 1997: 7). To create the categories high, medium high, medium low and low technology, the OECD estimates expenditures for 12 OECD countries (Sweden included) for the time period 1991-1999 (OECD, 2005). The OECD classification has been stable since its inception. The industries that are defined as high-tech manufacturing according to NACE Rev. 2 are enumerated in Table A1 in the appendix.

of high-tech industry relates to high growth is particularly important because it forms the foundation of policy. We therefore formulate the second hypothesis related to R&D as follows:

Hypothesis 2: *Ceteris paribus, HGFs will be more common in manufacturing industries with greater R&D intensity.*

Again, if current policies targeting high-tech industries to promote high-growth firms were sound, one would expect us to be unable to reject this hypothesis. In view of the previous literature concerning the link between R&D and growth, we would expect a non-existent relationship, or possibly even a negative one, because HGFs appear, if anything, to be overrepresented in service industries according to the previous literature (Henrekson and Johansson, 2010).

This observation is also important for our third hypothesis, which is also informed by Rossi-Hansberg and Wright (2007), who demonstrate that high growth rates and standard deviations are related to the amount of human capital specific to the industry, e.g., special skills and training. Therefore, one would expect a positive link between industry human capital and the share of HGFs in that industry.

Because we lack access to any common measure of human capital in our database, we again turn to Eurostat, which defines knowledge-intensive service industries according to their share of tertiary workers.[3] Arguably, it is important to determine whether this definition is sounder in identifying fast-growers. This leads us to formulate our third hypothesis:

Hypothesis 3: *Ceteris paribus, HGFs will be more common in service industries with more human capital.*

Previous findings regarding the slight overrepresentation of HGFs in service industries, in conjunction with the abovementioned link identified between human capital and growth, leads to the expectation that we will be unable to reject this hypothesis.

3. Data and descriptive statistics

3.1 Data and the dependent variable

All limited liability firms in Sweden are required to submit annual reports to the Swedish Patent and Registration Office (PRV). The data used in this study are collected from PAR, a Swedish consulting firm that gathers economic information from PRV. Our data comprise all Swedish limited

[3] Eurostat bases its definition on the Frascati Manual, see OECD (2002) and Eurostat (2012: 12). The industries that are defined as knowledge-intensive services according to NACE Rev. 2 are enumerated in Table A1 in the appendix.

liability companies active at some point between 1997 and 2008, yielding a total of 164,808 firms and 1,401,684 firm-year observations. The data include all variables in the annual reports, e.g., profits, number of employees, salaries, fixed costs, and liquidity.

Because employment and sales are the two most common growth indicators in the HGF literature (Daunfeldt et al., 2014a), we use both of them to identify HGFs. We follow recent contributions (e.g., Daunfeldt et al., 2014a; Coad et al., 2014c; Daunfeldt and Halvarsson, 2012) and define HGFs as the one percent of firms in the economy with the highest employment or sales growth over a three-year time period.[4] Absolute measures of firm growth lead to a bias towards large firms, while relative growth measures lead to a bias towards small firms (c.f. Acs et al., 2008; Schreyer, 2000). The use of both measures is nonetheless widespread, and we use both for each growth indicator.[5]

To summarize, we measure growth in two different ways and thus arrive at four groups of HGFs, which we label absolute employment-HGFs, relative employment-HGFs, absolute sales-HGFs, and relative sales-HGFs. All four groups consist of the one percent of firms that exhibit the highest growth (under this combination of measurement and indicator) in the entire economy over a three-year period.

A limitation of most studies on HGFs is that they cannot distinguish organic from acquired growth, which means that firms can only be identified as HGFs because they have merged with another firm. Our data contain information on mergers and acquisitions, enabling us to distinguish between organic and acquired growth as a robustness check for our analysis.

To construct each dependent variable, we take the definitions of HGFs as our point of departure. Because we address four definitions of HGFs, we have four dependent variables to include in a regression framework. The four types of HGFs were defined as the one percent of firms that grew

[4] A number of studies have also used the Eurostat-OECD definition of HGFs. This definition requires HGFs to have at least ten employees at the beginning of the year and annualized employment (or sales) growth exceeding 20 percent during a 3-year period. However, Daunfeldt et al. (2014b) have shown that this definition excluded 95 percent of all firms in the Swedish economy during the period 2005-2008 and approximately 40 percent of all jobs created. We therefore chose not to use this definition when identifying HGFs. We furthermore considered longer time periods and other shares of the firm population, such as the three or five percent of firms with the highest growth. The results are very similar to those reported in the paper and have been omitted to save space. These results are available from the authors upon request.

[5] While some studies have used the so-called Birch index, i.e., growth measured with a combination of absolute and relative numbers (Schreyer, 2000; Lopez-Garcia and Puente, 2009), Hölzl (2014) demonstrates that the Birch index primarily captures absolute employment changes. We therefore elect not to use the Birch index.

fastest in the economy as a whole. Our dependent variables are industry specific and defined as the share of HGFs in an industry i, i.e.,

$$SHGFs_i = Number\ of\ HGFs_i\ /Number\ of\ firms_{i.}, \qquad (1)$$

where SHGFsi is measured at the 4-digit NACE industry level in the main regressions presented in Tables 2 and 3. The results for defining the dependent variable at the 3- and 5-digit levels are reported in conjunction with other robustness checks in Table 4.

Table A1 in the appendix reports the industry distribution of HGFs at the 2-digit NACE-level. Because HGFs are defined as the fastest growing 1 percent of firms in the overall economy, it follows by definition that an industry has an overrepresentation/underrepresentation of HGFs if the share of HGFs in the industry is higher/lower than 1 percent. We follow the European Commission and Eurostat and classify NACE 2-digit industries as high-technology manufacturing according to R&D intensity and as knowledge-intensive services according to the share of tertiary educated persons (Eurostat, 2012).

In total, there are two manufacturing industries at the 2-digit NACE level that are classified as “high tech”: (21) manufacturing and pharmaceuticals and (26) manufacturing of computer electronics and optical products. Both of these industries have, on average, an overrepresentation of all types of HGFs except relative sales-HGFs. It remains unclear whether this actually concerns their R&D intensity or some other underlying characteristic. Regarding knowledge-intensive service industries, the view is fairly ambiguous, with some industries having an overrepresentation in HGFs and others having an underrepresentation.[6]

3.2. Independent variables

In our dataset, we have access to information on firms’ R&D expenditures, i.e., the total amount spent on R&D annually, which is believed to indicate the level of effort dedicated to producing future products and process improvements while maintaining the current market share and increasing operating efficiency (NSF 2010: 18–19). According

[6] The high-tech manufacturing sectors are (21) Manufacturing of pharmaceuticals and (26) Manufacturing of computer, electronics and optical products. The knowledge-intensive service sectors are (59) Motion picture, video and television programme production, sound recording and music publishing activities, (60) Programming and broadcasting activities, (61) Telecommunications, (62) Computer programming, consultancy and related activities, (63) Information service activities, and (72) Scientific research and development.

to Swedish accounting law, such expenditures are to be written down each year by a "reasonable amount", but by no less than one-fifth unless under special circumstances. This assumes a depreciation rate of 20 percent for the R&D stock, a reasonable rate given the findings of Bernstein and Mamuneas (2006), who find that R&D capital depreciates in approximately 3–5 years. [7]

R&D-intensity is a statistic that provides a means of gauging the relative importance of R&D across industries and among firms in the same industry (NSF 2010: 18–19). We compute it by taking the ratio of R&D expenditures to sales. We proceed by using industry R&D intensity to test hypothesis 1 in a first model specification. If the hypothesis holds, we expect to observe a positive coefficient for this variable.

We test hypotheses 2 and 3 in a second model specification. To test hypothesis 2, we use Eurostat's classification of high-tech industry, which is described in greater detail in section 3.2, as a measure of industry innovation activity, generating a dummy for high-tech manufacturing industries based on their R&D intensity. To test hypothesis 3, we employ the dummy provided by Eurostat to assess (high-tech) knowledge-intensive service industries, based on a high share of tertiary educated persons. For hypotheses 2 and 3 to hold, the dummies should exhibit a positive association with the share of HGFs in an industry.

Turning to our control variables, a measure of industry firm size is included to control for the fact that large firms make greater R&D expenditures, while the standard deviation of firm growth is smaller for large firms than for small firms (Stanley et al., 1996). Furthermore, there is evidence that HGFs, regardless of definition, are on average younger than other firms (Daunfeldt et al., 2014a). A number of studies on firm growth argue that firm age is negatively associated with growth (Evans 1987; Dunne and Hughes, 1999; Yasuda, 2005; Calvo, 2006; Haltiwanger et al., 2013), and a link may exist at the industry level. We therefore expect that firms in industries with older firms are less likely to exhibit rapid firm growth, due to a lower level of business opportunity (e.g., Coad, 2007: 40). The median firm age and the standard deviation of firm age within the industry are also included to assess whether industries with younger firms are more likely to have a higher share of HGFs.

[7] R&D is a durable input, as its productive capacity lasts for more than one time period. Consequently, accounting for the productive contribution of R&D should ideally involve an evaluation over several time periods. This nonetheless requires several assumptions, notably regarding the price of use and the price of ownership or purchase, where the price of ownership equals the discounted expected stream of future rental payments or user costs that the asset is expected to yield over time. Unobservability problems are inherent in all such calculations (cf. Jorgenson and Griliches, 1967; Hulten, 1990).

The size of an industry could also affect firm growth rates. For example, in the presence of geographic clustering, agglomerations within industries may create advantages in the form of spillovers and cooperation between firms (Krugman, 1992; Aghion and Howitt, 1992; Van Ort and Stam, 2006). There may furthermore be a bias towards observing a larger share of HGFs in small industries, due to what can essentially be considered a regression to the mean effect; industries with fewer firms should be more sensitive to having a large share of HGFs. Proxies for industry size, measured as the total number of firms and total employment in the sector, are included to capture this effect.

We further include measures of industry entry and exit to capture industry turnover. Arguably, industries with more turnover can be expected to be more conducive to high growth and hence have more HGFs (Johansson, 2005; Brown et al., 2006). In contrast, industries with a greater firm concentration can be argued to exhibit less high growth because a smaller number of market participants have a greater probability of overcoming collective action problems and collaborate to deter entry and small firm growth (Orr, 1974; Chappell et al., 1990; Geroski, 1995). We measure industry concentration using a Herfindahl index, which is computed as the sum of squares of firms' shares of industry revenue, i.e., $s_{1j}^2 + s_{2j}^2 + \ldots + s_{kj}^2$, where k is the number of firms.

Descriptive statistics for all variables included in our study are presented in Table 1. All variables are defined at the 4-digit NACE level. The descriptive statistics depict a rather heterogeneous picture, particularly concerning the four dependent variables. While the mean industry share of HGFs (of any kind) ranges between 0.01 and 0.03, the minimum share is 0, and the maximum share is 1 for all types of HGFs, other than relative sales-HGFs, for which the highest share is 0.67.