Schumpeterian Incumbents and Industry Evolution

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Abstract This essay explores the role of established firms in the evolution of innovative industries. Both direct and indirect contributions are discussed. Besides innovation in their own industries, established firms are often among the pioneering entrants into related markets. They enable spin-off entrepreneurship and provide exit options for startups through acquisition. Furthermore, established firms help shape and directly support public research activities. The multiple roles of established firms, their interaction with new entrants in the innovation process, and the dynamics on industry evolution in an increasingly globalized world are not sufficiently well understood.

1 Introduction[1]

"Schumpeterian entrepreneur" is a frequently used term in economics as well as in the broader populace. It generally characterizes the founders of innovative startups. Often, these startups are juxtaposed to rigid incumbent behemoths that are unwilling and/or unable to develop innovative products or processes. This essay will argue for a more nuanced view on established firms. There are indeed many instances of industry incumbents failing to react to innovative challenges or even proactively pursue innovations. At the same time, a sizeable theoretical and empirical literature shows that larger firms have stronger incentives to innovate, that incumbents often drive innovative changes in their own industries, and that established firms are

[1]This essay is based on a plenary talk given at the 2014 International Joseph A. Schumpeter Society Conference in Jena, Germany. I am grateful for a number of helpful comments and suggestions. The ideas expressed in this essay are strongly shaped by countless discussions with the late Steven Klepper, and also by his eminent contributions to entrepreneurship and industry evolution.

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pioneering entrants into newly emerging markets. Incumbents moreover enable innovation by involuntarily training future entrepreneurs, by providing exit options for startup founders and investors, and by supporting public research. Thus, there are multiple ways in which established firms directly or indirectly contribute to innovation and drive industry evolution. These contributions justify the characterization of (some) established firms as "Schumpeterian incumbents". It is the purpose of this essay to draw attention to these contributions, and also to their implications for future research on industry evolution.

Arguing that both established and new firms can be innovative is of course anything but original. More than 100 years ago Schumpeter already allowed for both possibilities. Even though this *Theory of Economic Development* (Schumpeter 1911/1934) highlighted the role of individual innovators, it also recognized that some innovation was realized by large established firms. In Schumpeter's later work, incumbents took center stage in the innovation process (Schumpeter 1942). Inspired by these contributions, a sizable empirical literature has explored the relative merits of small versus large, as well as young versus old, firms in the innovation process. This research has led to numerous important insights and an improved understanding of both innovation and industrial dynamics. These achievements notwithstanding, we still do not fully understand the interaction of different types of firms in the dynamics of innovative change. It therefore seems about time to shift the conceptual focus from innovation "beauty contests" between startups and incumbents toward a more "systemic" view on how their activities interact and jointly drive the evolution of innovative industries.

The remainder of this essay is organized as follows. Section 2 discusses findings on innovation by industry incumbents. Sections 3 and 4 focus on diversification and the role of incumbents in the spin-off process. Section 5 proposes that acquisitions by incumbents are important to induce startup entry, and Sect 6 calls attention to the role of established firms in performing and inducing basic research. Implications for future research are presented in the concluding remarks of Sect 7.

2 Incumbents Are Important Innovators

How innovative are incumbents compared to new entrants, in particular startups? This is a key issue in the economics of innovation and industry evolution. Many have suggested that incumbents are structurally disadvantaged vis-à-vis entrants. A variety of reasons for incumbent failure in the face of "competence-destroying" (Tushman and Anderson 1986) innovations have been suggested. As established organizations, incumbent firms are constrained by the imprint they received at the time of founding (Stinchcombe 1965) and subject to structural inertia that limits their capacity to adapt to environmental change (Hannan and Freeman 1984). Internal division of innovative labor along product components may restrict incumbents in their ability to cope with "architectural" innovation altering the linkages between product components more than the individual components themselves (Henderson and Clark 1990). Subsequent work by Christensen famously

emphasized incumbents' excessive focus on existing customers as a source of failure (Christensen 1993; Christensen and Rosenbloom 1995). His notion of "disruptive innovation" has attracted a great deal of attention among management scholars as well as practitioners, and "disruption" has become a buzzword (not only) in the Silicon Valley entrepreneurship community (Lepore 2014). But how general are these concerns? Are we really seeing that most innovations are introduced by new entrants, let alone startup or *de novo* entrants?[2] At least three bodies of literature suggest otherwise: first, empirical work on productivity changes in industries showing the importance of incumbents' increasing productivity, second, work inspired by the so-called "Schumpeter hypotheses" suggesting that larger firm size and market concentration are conducive to innovation, and third, the related work on industry evolution.

The development of productivity levels within firms and industries provides a first impression on how incumbents contribute to the development of industries.[3] While the discussion on measuring and explaining productivity is ongoing, existing work shows that growing productivity of existing firms substantially contributes to overall productivity increases (e.g., Cantner and Krueger 2008; Foster et al. 2008; Krueger 2014). In addition, more productive incumbents also tend to grow faster than less productive competitors. This evidence is relevant for the present discussion inasmuch as productivity changes are driven by innovation.

The literature on firm size and innovation is informative in the present context because firm size and age are not independent. While small firms need not be young, very few firms start big. The vast majority of large firms entered small and have taken years to grow to their present size (cf., e.g., Cabral and Mata 2003). Empirical results on the innovation performance of large firms can therefore tell us something about incumbents. A proportional relationship between firm size and R&D expenditure is generally observed, but the productivity of R&D efforts seems to decrease with firm size. In addition, smaller firms tend to engage in more radical innovation, whereas larger ones focus more on incremental and process-oriented innovation (cf. Cohen 2010, for a survey of the underlying literature).[4]

The cost spreading model (Cohen and Klepper 1996) can account for these findings. It is based on the insight that firms with large output volumes of a given product have stronger incentives to generate cost-reducing process innovations.[5]

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[2]There is an important difference between new firm formation and entry into new industries. New entrants into an industry are not necessarily newly established firms. A conceptual distinction is therefore made between *de novo* entrants, i.e., new ventures, and *de alio* entrants, i.e., firms that have already been active in other industries. Hybrid forms also exist (cf. Helfat and Lieberman 2002).

[3]I am grateful to an anonymous reviewer for making this point.

[4]There is little systematic research into whether new entrants, notably startups, are particularly prone to generate radical innovation (Cohen 2010).

[5]A crucial assumption underlying the cost-spreading model is that there are no well-functioning markets for technology and firms engage in R&D activities for their own use (cf. Cohen 2010, for a discussion).

Costs of R&D do not increase if the ensuing process innovation is applied to a large production volume. This entails that costs of R&D *per unit output* decrease with increasing output scale, providing the larger firm with a stronger incentive to engage in R&D. With diminishing returns to R&D, the ability of larger firms to spread their R&D expenditures over a larger output base can also explain their poorer R&D productivity, as more marginal R&D projects may still be profitable for them, but not for smaller competitors. Importantly, then, it is differences in incentives, not capabilities, that underlie the lower R&D productivity of larger firms.

Innovation by entrants and incumbents has also been explored in the theoretical and empirical work on industry evolution (cf. Peltoniemi 2011, for a survey). In stark contrast to the conjectures about incumbent failure discussed above, this literature suggests and finds that incumbents may have systematic advantages over entrants in innovation. Klepper's (1996) seminal model of industry evolution incorporates the cost spreading model originally developed to understand the relationship between firm size and innovation. In this model profitable firms grow. The larger (and therefore older) they are, the stronger are their incentives to invest in cost-reducing process innovation and to grow further. Cost spreading thus generates dynamic increasing returns to process R&D, providing early entrants with a sustainable competitive advantage over later ones.

Given the disparate predictions derived from different theoretical perspectives, incumbents' (dis-) advantages in innovation are an empirical issue. In part drawing on data collected by other authors before (Abernathy et al. 1983, for automobiles; Warner 1966, for tires), Klepper and Simons (1997) have shown that in the U.S. automobile industry, the two market leaders, Ford and GM, accounted for 34% of the major product innovations before 1940, considerably below their joint market share. In contrast, both firms accounted for 21 of the 27 (or 78%) major process innovations listed for this time period, which exceeded their joint market share. An even more favorable (from the incumbent perspective) picture emerges for the historical U.S. tire industry, where incumbents dominated both process and product innovation (Klepper and Simons 1997). In particular, with cord and balloon tires they pioneered the most significant product design innovations introduced before World War 2. Numbers of tire-related patents confirms these results (Buenstorf and Klepper 2010). In the industry's first three decades, only a minority of firms had any patents, and those which did tended to be large. The Top 5 producers consistently accounted for more than 75% of all patents, which was considerably above their joint market share.[6]

[6]Other research has pointed out that U.S. tire producers eventually lost their dominance when they were challenged by the ascent of the radial tire in the 1970s (Sull 2001). It is noteworthy in this context that the radial tire was not introduced by innovative startups, but by established European producers (in particular, Michelin from France) diversifying into the U.S. market. A similar account can be given for the decline of the U.S. automobile industry after the entry of Japanese producers. Diversifying entry will be in the focus of the subsequent section.

The U.S. automobile and tire industries are well-known examples of industries that experienced severe shakeouts early in their evolution. A striking contrast is provided by the U.S. laser industry, where no shakeout was observable 35 years into the industry's history. Bhaskarabhatla and Klepper (2014) developed a theoretical model to explain the development of "submarket" industries such as lasers. In these industries a multitude of product types compete in separate submarkets, because substitutability across product types is severely limited and there are no pronounced economies of scope. As in Klepper (1996), the model is driven by dynamic increasing returns based on cost spreading for process innovations. However, initially all submarkets are too small to justify investments into process R&D. The dynamics of the Klepper (1996) model set in only when unexpected technological change gives rise to an escalation of R&D efforts causing one of the submarkets to grow. This growing "integrative" submarket successively gains in importance, while other submarkets become obsolete, which causes a shakeout at the aggregate industry level. Based on their stronger incentive to (process) innovate, the earliest entrants into the integrative submarket grow to dominate first this submarket and subsequently the entire industry.

Bhaskarabhatla and Klepper (2014) argue that diode-pumped solid state (DPSS) lasers constituted an integrative submarket and led to a severe shakeout of U.S. laser producers beginning in the mid-1990s. They show that the leading patenters in the core technology of this submarket (wavelength conversion) were Coherent and Spectra Physics, two early entrants into the laser industry and then the two largest U.S. laser producers. Both firms aggressively entered the new submarket, producing a larger variety of DPSS lasers than most of their competitors.

As these examples suggest, it is too simplistic to view incumbents as being large, bureaucratic behemoths that are blown away as soon as seriously innovative new entrants enter the stage. It is easy to find further evidence against a too pessimistic view on incumbents. For instance, established producers accounted for large shares of early entrants into new submarkets in the U.S. diagnostic imaging industry (Mitchell 1991). In the contemporary global automobile industry, incumbent producers are leading radical innovations such as hybrid and fuel cell vehicles (Toyota), electric automobiles (GM, Nissan/Renault and BMW—but of course also Tesla as an innovative new entrant), and even car-sharing platforms (BMW, Daimler).

In spite of this evidence, we still do not fully understand which incumbents are more successful and under what conditions they are able to outcompete entrants. As noted above, there is substantial evidence that incumbents tend to focus on the more incremental and process-oriented innovations. Possibly, however, it is not incumbency itself but rather a lack of competition in mature, oligopolistic industries that makes incumbents prone to complacency and thus vulnerable to innovative entry. In line with this conjecture, the DPSS laser was introduced in an industry that had not yet experienced a shakeout in the number of active producers, and competition in the global automobile market is intense.

3 Incumbents Diversify and Innovate in Related Industries

As the literature on industry evolution shows, the innovation performance of established firms can often not be assessed based on individual markets alone. Just because innovators come from outside an established industry they are not necessarily startups. As an illustrative case in point, consider Apple's iPhone, the radical innovation that disrupted the global market for mobile telephones. When the first-generation iPhone was launched in 2007, Apple Computers Inc. was 31 years old and, according to its 2006 Annual Report, had about 18,000 employees. Clearly, then, the iPhone was not developed by an entrepreneurial startup, but by a successful established firm that diversified into the market for mobile phones. In doing so Apple leveraged the capabilities it had previously built up in the computer and music player markets.[7]

Diversification of established firms into new markets is a "natural" phenomenon. It enables these firms to re-deploy resources that have been made redundant by organizational learning (Penrose 1959/1995). The crucial role of diversifying entrants in the emergence and evolution of industries has been demonstrated in a variety of industry contexts. Diversifying bicycle, carriage and engine producers figured prominently in the early history of the U.S. and German automobile industries (Klepper 2002; Cantner et al. 2006). In the German industry, the share of innovators was twice as large among experienced entrants as among non-experienced ones (Cantner et al. 2009). Similarly, the first U.S. pneumatic automobile tire was introduced in 1986 by B.F. Goodrich, a rubber goods producing firm established 25 years before (French 1991). The U.S. television receiver shows an even more extreme pattern (Klepper and Simons 2000). Not only were diversifiers from the radio industry numerous in this industry, but there was not a single significant TV producer that had *not* diversified from radios. Diversifying radio producers, in particular the larger ones, were also more innovative than other entrants. More recently, many of the pioneering entrants into the U.S. and German laser industries were diversifiers from electronics, optics, or mechanical engineering (Sleeper 1998; Buenstorf 2007).

These examples illustrate that the innovative record of incumbents is grossly underestimated when only their current industries are taken into account. Incumbents in one industry can be innovative diversifying entrants in other, often related, industries. Diversifiers account for a substantial share of entrants in many industries, and are often found among the pioneering innovators. This tendency of innovative diversification into related markets has important implications for the economic development of regions and entire economies. As Frenken and Boschma (2012) highlight in their "branching theory", it entails that new industries frequently

[7]Note also the similar origins of the conventional mobile phone that the iPhone successfully challenged. The mobile phone had first been commercialized in 1983/1984 by Motorola, then 55 years old, and Nokia, then 119 years old. Both firms were diversifiers with substantial experience in related markets.

emerge where related earlier industries are already found, thus giving rise to regional path dependence (Martin and Sunley 2006) and long-term regional imbalances. A similar argument can be made at the level of entire economies (Hidalgo et al. 2007).

4 Incumbents Are Seedbeds of Innovative Spin-Offs

The previous two sections focused on the innovative performance of established firms as incumbents in their own markets and as diversifying new entrants into related industries. This and the following sections will further broaden the perspective. They will argue that established firms make contributions to the evolution of innovative industries that go beyond their own innovation activities. To begin this discussion of indirect or enabling effects of incumbents, first their role in spin-off entrepreneurship will be scrutinized.

(Intra-industry) spin-offs are defined as entrepreneurial ventures started by former employees of incumbent firms active in the same industry that the spin-off enters. Spin-off entrepreneurship has received substantial scholarly attention in the past decades. Time and again, spin-offs have been found to outperform other types of *de novo* entrants and to be similar to diversifiers in their success (Klepper 2009). To date, there is no conclusive evidence showing that the performance of spin-offs is due to on-the-job learning of subsequent spin-off entrepreneurs. However, several empirical patterns are consistent with spin-offs benefitting from their founders' prior experiences. For instance, more successful incumbents tend to have more spin-offs, and their spin-offs are generally higher performers than those of humbler origins. The first-generation products of spin-offs moreover tend to be similar to those made by the parent firm (ibid., Golman and Klepper 2016). These patterns suggest that spin-off founders indeed acquired useful knowledge on their prior jobs, and that superior incumbents are superior training grounds for aspiring entrepreneurs.

A recurrent pattern in the spin-off process is that employees develop some innovative variant to the parent firm's product and/or some modification of the parent's strategy, and leave the parent firm after they fail to find support for their innovation from the firm's management (Garvin 1983; Klepper and Thompson 2010). Incumbents thus enable their employees (and future spin-off entrepreneurs) to generate new knowledge resulting in innovative products and processes, but are often unable or unwilling to employ this knowledge in the market. Empirical findings from the U.S. disk drive industry (Agarwal et al. 2004) nicely illustrate this tension. In this industry, both the technological capabilities of incumbent firms and their market-pioneering know how (proxied by early entry into new product submarkets) were associated with a higher propensity of (involuntarily) spawning spin-offs. However, the interaction effect of both types of capabilities was significantly negative. This indicates that spin-offs primarily formed in firms that produced more knowledge than they utilized themselves.

As others have pointed out before (e.g., Klepper and Sleeper 2005), incumbent firms may have good reasons not to pursue an innovative technology that they have developed. Product innovations may "cannibalize" their existing products and threaten their legitimacy or organizational identity (Hannan and Freeman 1984; Hannan et al. 2006). In other cases, failure to commercialize new technologies may reflect poor managerial decision making. Or highly innovative firms such as Intel may simply generate more employee inventions than they could possibly commercialize (Moore and Davis 2004). Either way, spin-off entrepreneurship is important to prevent the new technology from being "shelved". Incumbents then have an ambiguous role in the spin-off process. On the one hand, they are the ones that—for whatever reason—fail to innovate. But on the other hand, they provide the context in which the underlying invention is made. In this sense, incumbents enable innovative spin-off entrepreneurship. To the extent that the innovative technology could not, or not as quickly, have been developed in a different environment, they thus contribute to the evolution of the industry (and sometimes to their own eventual demise).

In this perspective, a "hotbed" of spin-offs such as Fairchild Semiconductors deserves credit for the innovations of its spin-offs (the proverbial "Fairchildren" including Intel and AMD), which contributed to the rapid development of information and communication technology as well as the ascent of Silicon Valley as the world's leading high-tech cluster. At the same time, spin-off entrepreneurship is one of the processes in which the interaction of incumbents and entrepreneurial entrants contributes to innovation and drives industry evolution. With the acquisition of startups by incumbents, a second form of interaction will be explored in the next section.

5 Incumbents Acquire Innovative Startups

Firm exit is a key element in the population dynamics of industry evolution. Even in industries that have not (yet) experienced a shakeout in the number of active firms, pronounced "churning" is generally observed within the firm population, with substantial numbers of firms entering and exiting the market. A large number of studies of industry evolution have analyzed firm performance using longevity as a performance measure, and exit as an indicator of poor performance. These studies often acknowledge that not all firm exit is equally indicative of failure. The precise nature of exit is rarely explored, however (for a notable exception, cf. Krueger and von Rhein 2009).

In many industries acquisition events contribute substantially to the observed rates of firm exit. When firms exit because they are acquired by another firm (often a larger competitor), it is particularly problematic to interpret their exit as indicating poor performance. Being acquired by a competitor may indeed constitute the last resort of a failing firm to prevent impending bankruptcy. However, in many cases acquisition reflects success rather than failure. In some contemporary industries, the

acquisition of innovative startups by large incumbent firms with superior production and distribution capabilities to profit from innovations is a pervasive phenomenon. It is observable, for instance, in the laser industry, where large incumbents such as Coherent and Spectra Physics have acquired many of their smaller competitors. This has enabled them to broaden their product portfolios and to serve a wider spectrum of customer needs.

The importance of acquisition events has attracted attention in several lines of literature, including the research on university technology transfer. Studying the commercialization of inventions from the University of California system based on licensing to incumbents and inventor startups, Lowe and Ziedonis (2006: 183) observe: "Virtually all inventor-founded start-ups that commercialized an invention were acquired, and all but two of these firms were acquired prior to commercialization. Most unacquired firms remain in product development with no significant sales." Similarly, the division of labor between biotechnology inventors and pharmaceutical commercializers is a well-established pattern of innovation (cf., e.g., Powell et al. 2005).

Where acquisitions of innovative startups by incumbents are widespread, the respective incumbents play another indirect role in the innovation process. They provide an important channel of profitable exit for founders and investors. If prospective entrepreneurs and investors of innovative startups have reason to expect that in the event of success they may sell their venture to an established firm, this will *ceteris paribus* increase the attractiveness of the venture and its chances to be organized and funded in the first place. The importance of acquisition as an exit strategy for investors has further increased since the ascent of professional venture capital firms, particularly in countries where (and at times when) IPOs are rare events. As a consequence, the role of incumbents in facilitating entry through being potential acquirers has also been strengthened. And obviously, this role is even more important if incumbents become corporate venture capitalists themselves.

6 Incumbents Perform and Induce Basic Research

The corporate R&D laboratory was one of the key organizational innovations of the nineteenth century (Hounshell and Smith 1988). Its diffusion resulted in major shifts in the innovation process, which in turn helps explain the shifting locus of innovation suggested in Schumpeter's writings. Most research performed in corporate R&D laboratories is of an applied nature and directly feeds into the respective firm's innovation output. But this is not universally true: corporate R&D labs also engage in basic research activities. These activities warrant attention as another indirect contribution that incumbent firms make to the evolution of innovative industries.

By its very nature, basic research is fraught by uncertainty regarding its success as well as its range of potential applications. In his pioneering work on the

economics of innovation, Nelson (1959) suggested that more diversified firms are more likely to engage in basic research because they are more likely to find a useful application of its uncertain results. This application may be within the scope of their existing activities, in which case basic research adds to their innovative performance in their industry of origin. In other cases, basic research activities may lead to results that motivate incumbents to diversify into new markets. Unexploited findings of incumbents' basic research activities may lead to spin-offs with or without parent firm involvement (a prominent case in point is Xerox PARC, cf. Chesbrough 2003).

A recent popular book (Gertner 2012) relates the history of the Bell Labs, AT&T's R&D laboratories that arguably constituted the most important corporate R&D establishment in history. The Bell Labs were the birthplace of numerous key discoveries and inventions. New knowledge from the Bell Labs provided the foundation of present-day high-technology industries, and also of a number of Nobel prizes. Scientists at the Bell Labs also invented or co-invented some of the technologies extensively studied in the empirical literature on industry evolution, including the transistor and the laser. This provides direct evidence that established firms can be crucial in the emergence of innovative new industries.

The Bell Labs were an extreme case of basic research activities by large firms. However, they were not unique. As an example from a different empirical context, consider the German Siemens firm and its entry into laser research in the early 1960s (Albrecht et al. 2011). Siemens' first laser was constructed in 1960/1961 by Dieter Röss, a young university graduate who had recently joined the firm's central research laboratory (Albrecht 1997). Röss (personal communication) enjoyed far-reaching autonomy to choose his objects of research. He had become interested in laser technology because he sensed it might become relevant for Siemens. However, much in line with the well-known quip that the laser initially was a solution in search of a suitable problem, Röss started his research into lasers without having a specific market or product in mind. He was able to initiate contacts to some of the leading U.S. research groups and quickly managed to catch up to the global frontier of laser research (Albrecht 1997). In 1961, Röss constructed an improved laser design, and subsequently Siemens became a pioneering producer in the German laser industry.

Other well-known examples notwithstanding, the role of incumbents' research activities in the, as it were, prehistoric phase on industry evolution has not been explored in much detail. It is conceivable that the direct involvement of incumbents in basic research has become less important in recent decades as competitive pressure and short-term profit orientations have tended to increase. Even if this were true, however, incumbents could still exert a relevant influence on basic research activities. Substantial evidence suggests that established firms help shape the research agendas of universities and government labs, thereby inducing basic research activities that promise to contribute to their own innovativeness. While possibly quite important for how innovative industries evolve, this indirect effect of incumbents on public research has largely been neglected in the empirical work on industry evolution. In contrast, reverse influences of universities and government

labs on innovation and industry evolution have figured more prominently (cf., e.g., Stuart and Sorenson's (2003) work on U.S. biotechnology).

A detailed account how incumbent firms and related public research activities mutually condition and support each other is provided by Murmann's (2003, 2013) comparative historical study of the synthetic dye industry. Murmann adopts the conceptual framework of coevolution of industries and their environment (Nelson 1994) to highlight that the two are interdependent. While Murmann's historic case study presents substantial evidence of firms benefiting from public research, his findings on the "reverse" effects of dye producers on public research activities are most relevant from the perspective of this essay. Murmann (2013) stresses three conduits through which such effects were realized: exchange of personnel, commercial ties, and lobbying on behalf of research facilities that were of interest to the synthetic dye producers. He shows that industry demand for organic chemists influenced the structure of chemistry departments, that access to collaboration partners and industry grants affected the location choices of leading scientists, and that lobbying efforts contributed to the establishment of new government labs.

Using a conceptual framework similar to the one adopted by Murmann, Blankenberg and Buenstorf (2016) study the regional coevolution of firm population, private-sector R&D and public research in the more recent context of the German laser industry. Similar to the historical dye industry, qualitative evidence suggests that laser producers not only benefited from public research activities but also exerted a non-negligible influence on the scope and direction of these activities. Blankenberg and Buenstorf (2016) begin to quantitatively address these coevolutionary dynamics. For this purpose they utilize regional data on firm populations spanning over a 45-year period from the outset of the German laser industry. They combine these data with information about laser-related patent applications from the private sector, as well as with scientific publications and laser-related doctoral dissertations as proxies of public research activities. To probe into the idea of regional coevolution, they estimate a set of reduced-form vector autoregressions considering changes in firm population size, private-sector innovation and public research activities at the level of West German planning regions. For a variety of alternative lag lengths Granger causal relationships are obtained for the effect of public research on private sector activities, but also for the reverse effect of regional firm population size and private-sector patent output on laser-related public research activities. These results are consistent with the idea of coevolution. They indicate that, via their effect on public research, incumbents may perform another relevant indirect role in the evolution of innovative industries.

7 Concluding Remarks

What is the contribution of incumbent firms to innovation and industry evolution? In other words, how and in what sense can incumbents be "Schumpeterian"? To approach this issue, the present essay drew on diverse lines of scholarly work. It

touched upon several processes through which established firms directly or indirectly influence innovation activities within and outside their own industry. These processes have all found some attention in the diverse literature on innovation. However, they are reflected to differing degrees in the theoretical and empirical work on industry evolution.

Starting point of the essay was the literature on firm size and R&D. I then broadened the focus and called attention to the importance of diversifying established firms as innovative entrants into new markets. I also emphasized the role of incumbents in (involuntarily) breeding innovative spin-off entrepreneurs. Diversification and spin-off entrepreneurship both figure prominently in the research on industry evolution. In contrast, little has been written in this literature about acquisition as an exit strategy for innovative startups. As has been argued above, acquiring competitors is another indirect role of incumbents in fostering innovation. By signaling the existence of profitable exit through acquisition, incumbents may induce the entry of innovative startups. This also allows them to "outsource" innovation activities for which startups may be better suited than they are themselves, and provides opportunities for mutually beneficial collaborative R&D projects (cf., e.g., Baum et al. 2000). We also know little about the extent to which industry incumbents are able to shape their environment, for instance by inducing public research to address issues that are relevant for their own innovation efforts.

The above discussion suggests at least four issues that future work on industry evolution could (and, in my view, should) address. First, the "division of innovative labor" between incumbents and startups is not fully understood. To improve our knowledge, it would seem fruitful to de-emphasize the relative merits of different types of firms as innovators and focus more on how these types of firms interact. Part of this interaction are the more indirect, enabling roles that incumbents may take in the innovation process. These indirect roles imply that innovative startups may require the presence of successful incumbents, and that successful incumbents may be the origin of self-reinforcing dynamics of industry evolution at various geographic scales. They also suggest that the evolution of innovative industries takes places in a broader systemic context including, among others, universities, policy makers, customers, suppliers, and horizontally related firms. This relevance of a broader context that exceeds the boundaries of a single industry, and is itself shaped by the evolution of the industry, is a core tenet of the work on innovation systems (e.g., Lundvall 1992; Nelson 1993; Malerba 2002)—a literature that still has the potential to enrich the research on industry evolution. At the same time, the population-based, dynamic approach taken in the empirical work on industry evolution has much to offer to inform empirical research on innovation systems and their evolution.

Second, we know little about how the various processes and interactions change over the life cycle of an industry. Existing evidence suggests that diversifying *de alio* entrants are most important in the early stage of a new industry, whereas spin-offs by their very nature can only emerge from incumbents that have entered before. But how does, for example, the importance of acquisitions change over time, and is

the interaction with public research becoming more or less important as industries mature? More theoretical and empirical work seems to be required to provide answers to questions like these.

Third, and perhaps most importantly, the evolution of industry evolution is largely a black box. We know from the broader work on innovation that markets for technology are getting increasingly well established. As has been suggested before (Cohen 2010), increased tradability of technology may have profound effects on how industries evolve and on the extent to which first-mover and size advantages still matter. Other developments may also change the dynamics of industry evolution. These include the increasing societal interest in and policy support for entrepreneurship, which may affect the frequency but also the motivation and behavior of spin-off entrepreneurs. A similar case can be made for the increasing attention that policy makers (as well as university administrators) pay to industry-science interaction and technology transfer from public research. Last but not least, we are witnessing the rapid global expansion and integration of markets, which so far has not been sufficiently well addressed by the research on industry evolution. The widespread tendency to study national firm populations may be less and less appropriate in a world in which markets are increasingly global and the geography of industries may shift at a very rapid pace. Only a small number of internationally comparative studies on industry evolution have been produced (e.g., Chesbrough 1999). A more global outlook on industries will increasingly be required in future research.

In summary, there is still much to learned about industry evolution and how it is affected by Schumpeterian firms—both Schumpeterian startups and Schumpeterian incumbents.

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