Industrial dynamics and economic geography: a survey

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Abstract: Research at the interface between industrial dynamics and economic geography has witnessed a growing popularity not in the least because entrepreneurship and clusters are topics that rank high on regions' policy agenda. We review the literature on clusters and their effects on entry, exit and growth of firms as well on various lifecycle dynamics underlying the process of cluster formation and cluster dynamics. The review shows that there is strong evidence that clusters promote entry, but little evidence that clusters enhance firm growth and decrease their hazard to exit. In the absence of agglomeration economies, the emergence of clusters is best understood as an evolutionary process of capability transmission between parents firms and their spinoffs. Following this view, clusters can extend their lifecycles by diversifying into related industries. From a number of open questions we distil various future research avenues stressing the importance of understanding firm heterogeneity, industry specificity and the exact mechanisms underlying agglomeration economies.

Keywords: entry, exit, industrial cluster, localisation economies, urbanization economies, product lifecycle, industry lifecycle, cluster lifecycle, evolutionary economic geography, firm heterogeneity

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1. Introduction

The field of industrial dynamics is a relatively young field of study, yet has roots in the works of Alfred Marshall, Joseph Schumpeter and Edith Penrose. Its main topic is the evolution of industries with a focus on entry, growth and exit dynamics of firms (Carlsson 1989; Malerba 2007). In contrast to the neoclassical approach to industries – commonly referred to as industrial organization – industrial dynamics focuses on phenomena that are inherently dynamic, and deals with these in an interdisciplinary manner. One of the disciplines with which there is increasing cross-fertilisation is economic geography.

At the interface of industrial dynamics and economic geography, *the central question holds how clusters of economic activity can be understood from the entry, growth and exit of firms, and how, in turn, clusters affect entry, growth and exit patterns through agglomeration economies.* These questions are not only of academic interest, but are also of policy interest as high rates of entry and exit are generally associated with growth in employment and productivity (Fritsch 2011, for a recent review). In this context, the understanding how clusters emerge and how these in turn affects rates of entry and exit has become a core question among economists and geographers alike. Witnessing the increase in theoretical and empirical studies in this 'interface-field', time has come to take stock of the progress made so far and questions that still remain.

The field of industrial dynamics can be delineated in a broad sense and a narrower sense (Malerba 2007). In a broad sense, the field deals with all questions related to the process of industrial transformation including the growth of firms, entry and exit dynamics, the co-evolution of technology, market structure and institutions, and the impact of structural change on macroeconomic growth (Carlsson 1989) as well as the analysis of changes in demand, the knowledge base of industries and the structure and dynamics of innovation networks (Malerba 2007). In a narrower sense, industrial dynamics can be taken to refer to the demography of industries in terms of the dynamics of entry, growth and exit of firms underlying the growth and decline of industries, where entry can be broken down further into de novo start-ups versus spinoffs and exit into acquisition versus failure. For the purpose of this survey, we choose to define the field of industrial dynamics in the narrow demographic sense, as to be able to provide a systematic and comprehensive review. Throughout the review, we will primarily focus on empirical research and less on theoretical frameworks. In doing so, we will draw primarily on evolutionary economic geography as our interpretative framework (Boschma and Frenken 2006). This choice is not coincidental as the field of industrial dynamics and literature of evolutionary economics emerged around the same time in the late 1970s and show considerable overlap in intellectual origins en key contributors (Malerba 2007).

Following our aforementioned definition of the interface between industrial dynamics and economic geography as the study 'how entry, growth and exit of firms lead to spatial clustering, and how, in turn, clusters affect entry and exit patterns through agglomeration economies', a review naturally breaks down in two parts. One part on the latter question how agglomeration economies affect entry, exit and growth (section 2). We focus on the question how economies stemming from clustering of firms in the same or related industry, known as localisation economies, affect entry, growth and exit of firms. The other part deals with the question how entry, growth and exit patterns lead to spatial clustering and cluster dynamics (section 3). we will consider spatial clustering as an evolutionary process that can be studied from various 'lifecycle' perspectives: the *spatial product lifecycle* where the location of new industries and their relocation dynamics are derived from underlying patterns of technological change, the more recent *industry lifecycle* approach and its emphasis on spinoffs dynamics leading to the formation of clusters, and the very recent *cluster lifecycle approach* looking at the evolution of single clusters as a process of collective learning. We end with a short summary of the main findings and the conclusions that can be drawn from these (section 4). From this, a discussion follows on future avenues for research (section 5).

2. Industrial dynamics, clusters and economies

2.1 Firm entry

Firm entry is the result of the interaction between the characteristics of an actor – an entrepreneur or a founding organization – on the one hand and the surrounding environment on the other hand. The factors determining entrepreneurial foundings differ from those that determine organizational foundings. Regional variations in entrepreneurial foundings can be the result of two groups of factors: compositional factors, reflecting an over- or under-representation of 'entrepreneurial' population characteristics, and regional factors. Regional variations in organizational foundings are more likely to be driven by real estate costs and market access, in order to achieve scale economies (Stam 2007; Koster 2007). Organizational foundings are also less hindered by an oligopolistic local market structure than entrepreneurial foundings (Bosma et al. 2008). Most individual founders start their venture in their own region (Figueiredo et al. 2002; Stam 2007), while organizational foundings are more likely to be established outside the home-region of the firm headquarters. In this section we will mainly focus on the determinants of entrepreneurial entry, because these are much more numerous than organizational foundings. We can start the explanation of regional differences in entrepreneurial entry with the spatial distribution of *personal characteristics* associated with entrepreneurship. Conceptually, the entrepreneurial process involves opportunity identification and exploitation (Shane and Venkataraman 2000). Some people are more perceptive to either or both elements, for instance because they possess more general or specific human capital, than others. Bosma (2010) shows that personal characteristics such as age, education level, and household income strongly contribute to the probability of becoming an entrepreneur. Relatively high urban entrepreneurship rates therefore can be an effect of its population composition, as urbanized areas are often concentrations of educated individuals with business experience in their early and middle adult years (Glaeser 2007). Note, however, that the regional composition of population characteristics is only part of the reason why regional entry rates vary. The other part is related to the strong inclination for entrepreneurs to locate their business in their home region (Stam 2007). The fraction of entrepreneurs working in the region where they were born is significantly higher than the corresponding fraction for dependent workers (Michelacci and Silva 2007). A study of Portuguese manufacturing firms found that entrepreneurs were willing to accept labour costs three times higher than in alternative locations to locate the new business in their current region (Figueiredo et al. 2002). A Danish study (Dahl and Sorenson 2011) found that firms perform better - survive longer and generate greater annual profits and cash flows - when located in regions in which their founders have lived longer. This effect appears substantial, similar in size to the value of prior experience in the industry (i.e. to being a spinoff). The tendency to stay put, especially among (new) entrepreneurs, establishes the strong relation between regional population composition and regional entrepreneurship rates.

Although some individuals start a business without prior experience in the business they operate in, they are the exception rather than the rule. Most entrepreneurs built up relevant experience as an employee and among them most display 'sectoral inertia', i.e. they start their firm as a spinoff in an industry with which they already were familiar as an employee (Storey 1982; Lloyd and Mason 1984; Vivarelli 1991). Far from the universal choice, entrepreneurial action is relatively constrained: instead of looking around to seek the most profitable opportunity, the potential entrepreneur concentrates his attention on a familiar sector. A person working in an industry is more likely to identify a market gap than a person without any industry experience, irrespective of the degree of industry competition and growth prospects (Agarwal et al. 2004; Gompers et al. 2005; Klepper 2009; Shane 2001).

Since entrepreneurs typically build on their pre-experience when founding a firm, the existing economic structure greatly affects the rate of entry in a region. That is, the more firms are active in a particular industry in a particular region, the more new firms will be created in that same industry and region. In the field of organizational ecology, closely related to the field of industrial dynamics (on this, see Geroski

2001), the positive effect of the number of incumbents on entry is more generally known as a social legitimation effect. Legitimation is generally loosely defined as "social taken-for-grantedness" (Hannan et al. 1995) and is assumed to rise with the number of incumbents in an industry, known as 'firm density'.

There are two main processes underlying social legitimation. First, the current stock of firms in a region: organizations generates business information that diffuses to potential entrepreneurs inducing them to start the same type of business, termed "cognitive legitimacy" (Aldrich and Fiol 1994, p. 648). A prime mechanism of cognitive legitimacy is the knowledge transfer that takes place between incumbent and entrepreneur before the latter creates a spinoff company (Sorenson and Audia 2000). A recent study showed indeed that an individual is more likely to become an entrepreneur if co-workers have been entrepreneurs before, reflecting better access to information and resources that help identify entrepreneurial opportunities, and peer effects from co-workers' perceptions about entrepreneurship as a career choice (Nanda and Sørenson 2010). Apart from cognitive legitimacy, socio-political legitimacy is also expected to rise with the number of incumbents. Socio-political legitimation refers "to the process by which key stakeholders, the general public, key opinion leaders, or government officials accept a venture as appropriate and right, given existing norms and laws" (Aldrich and Fiol, 1994: 648). Indeed, it has been found that entrepreneurs in a region provide social role models with the presence of other firms that have "made it", and a cultural environment where establishing one's own business is normal and failure is not a social stigma (Fornahl 2003; Vaillant and Lafuente 2007).

From the aforementioned processes of learning and legitimation, one would predict that the more firms in a particular industry are present in a region, the higher the regional entry rates in that industry. Put differently, one expects entry rates to rise with cluster size, where a cluster is defined here as a spatial concentration of firms in the same or related industry. Empirical evidence is indeed strong. In a comprehensive study covering more than half a million firm entries across all sectors in the U.S., it was found that the higher the number of new firms in a region, the higher its number of entries, both at the level of the entire economy and at the level of six broad economic sectors (Acs and Armington 2002) and more narrowly defined industries (Nyström 2007). Furthermore, numerous industry studies have found that regional firm density affects regional entry rates including computer industry (Baptista and Swann 1999), footwear (Sorenson and Audia 2000), accounting (Cattani et al. 2003), biotechnology (Stuart and Sorenson 2003), computer workstations (Sorenson 2005), motorcycles (Wezel 2005), fashion houses (Wenting and Frenken 2011) and video games (De Vaan et al. 2011a).[2]

Many interpret the association between localisation and entry rates as evidence of localisation economies, that is, of benefits firms accrues from co-locating with firms in the same or related industries. Localisation economies include the advantages of specialised labour markets, specialised suppliers and knowledge spillovers (Marshall 1920) as well as reduced costs of experimentation (Duranton and Puga 2001). Such benefits may attract new entrants to clusters, apart from traditional regional cost conditions that affect location decisions (such as transaction costs, transportation costs, and shared infrastructures). However, if the founder of a firm was already located in a cluster, the positive association between clustering and entry rates may simply reflect the high economic and social cost of relocation. Indeed, in studies on tires (Buenstorf and Klepper 2009) and lasers (Buenstorf and Geissler 2011), no evidence was found that entrants are drawn to clusters because of the presence of other firms, once controlling for their regional origins. Most founders prefer to locate in the region they are already located, reflecting the high costs of relocation (Figueiredo et al. 2002) as well as social ties (Dahl and Sorenson 2007).

[2] Importantly, not all studies in the organizational ecology tradition found that legitimation process are regionalised. Bigelow et al. (1997) found that regional founding rates of automobile manufacturers were positively affected by national firm density only. Similarly, Lomi (2000) found for Danish banks that, with the exception of banks in the capital, founding rates were affected by national firm density. Indeed, for service industries like banking, this can be understood from the cross-regional transfer of knowledge in multi-locational firms.

Though locational origins of founders may lie at the root of high entry rates in clusters, localisation economies may still play a role in entry decisions. One can analyse whether firms prefer to locate within or outside clusters in their particular region of origin. In a study controlling for region of origin, Pe'er et al. (2008) showed that most firms that enter are indeed drawn to clusters in their region of origin suggesting that (percieved) localisation economies played a role in location decisions. Localisation economies may also play a role in foreign entry. In this line of work, firm heterogeneity has been highlighted as firms that know less have much to gain and little to loose from clustering while firms that know more have little to gain and a lot to loose from clustering.[3] Shaver and Flyer (2000) indeed found that relatively small entries show strong evidence of agglomerating and relatively large entries are significantly less likely to agglomerate. Similarly, Alcácer and Chung (2007) find that technologically lagging firms are dawn to clusters with innovative firms, while technologically advanced firms avoid such locations, and prefer locations with high levels of academic activity.

2.2. Firm growth

Though there is a strong association between spatial clustering and firm entry, we have argued that this association does not provide us with clear evidence of agglomeration economies. As most entrepreneurs do not relocate when they found their own firm, the association between agglomeration and entry most probably reflect spatial inertia more than anything else. The impact of agglomeration economies can better be assessed by associating agglomeration directly to firm performance, including firm growth (this section) and firm survival (section 2.3).

Relatively few studies on localisation economies and firm growth have been carried out so far. So far, studies focused on estimating whether there is an association between localisation and firm growth, that is, whether localisation economies can be identified, without further probing the exact underlying mechanisms or sources of firm heterogeneity. One of the most comprehensive studies on firm growth and localization economies is the study by Beaudry and Swann (2009) on firm growth for 56 two-digit industries in the UK. In about half of these industries, there is a positive and statistically significant association between firm growth and own-sector employment. Significant associations between firm growth and total employment in other sectors (an indicator of 'urbanisation economies') are less common, but where these arise they are generally negative. Cluster effects are strongest in manufacturing and infrastructure industries, but weaker in services.

Other studies looked at firm growth of young firms specifically. For example, Rosenthal and Strange (2005) investigated all new plants in the greater New York metropolitan area in 2001 and found that specialization, measured as location quotients, was positively related to job creation among new firms. Similarly, Wennberg and Lindqvist (2010) analyze firm-level data for Swedish firms started in the telecom and consumer electronics, financial services, information technology, medical equipment, and pharmaceuticals and pharmaceutical sectors. They find evidence for localization economies when using absolute agglomeration measures (firm density or employee counts), yet evidence is substantially weaker when using location quotients as measures for localization economies. However, one can argue that agglomeration economies are best captures by absolute counts as benefits are expected to rise with the number of co-located firms in the same or related industry.

A related topic of research is whether firm growth is enhanced in regions with high knowledge-intensity. Such an effect would be especially indicative of the knowledge spillovers as one of the mechanisms underlying agglomeration economies. Stough et al. (1998) investigated the economic development of the greater Washington DC area in the United States and found that a high concentration of technically

[3] Note that the same reasoning holds for firms' incentives to engage in networks (Cassiman and Vleugelers 2002).

skilled workers is associated with higher levels of new firm growth. Raspe and Van Oort (2008) also found for all Dutch establishments that being located in a local innovative environment and an R&D-intensive environment is more conducive to firm growth than being located in a region that is less endowed with knowledge resources. This can be considered as evidence of agglomeration economies in the firm of knowledge spillovers

2.3 Firm survival

The studies that examine firm survival are usually based on survival or duration analysis which deals with firm death/exit from the market. Survival analysis involves the modelling of time to event data; in this context, the exit of the firm is considered an event in the survival analysis literature. The survival probability is therefore the complementary probability of the exit probability and those factors that influence positively the survival probabilities (that is, increase the firm chances to survive), at the same time influence negatively the exit probability (that is, decrease the firm chances to exit the market).

Several empirical studies in industrial dynamics document the impact of the firm's specific characteristics and industry features on firm's survival. Survival probability of firms, and consequently the probability to exit the market, varies less across industrial sectors than entry rates (Geroski, 1995; Audretsch et al., 1999; Audretsch et al., 2000). This fact has been interpreted as evidence that barriers to survival are higher than barriers to entry: it is easier to start a firm than to survive (Geroski, 1995). These barriers to survival have been primarily related to structural factors, such as firm size and age (see e.g. Evans, 1987; Hall, 1987; Doms, Dunne and Roberts, 1995, Geroski, 1995; Sutton, 1997; Caves, 1998); to traditional market structure variables, such as the presence of scale economies, other cost advantages of established firms, and the growth rate of sector specific demand (Audretsch, 1991; Audretsch and Mahmood, 1995; Dunne and Hughes, 1994; Mata and Portugal, 1994; Wagner, 1994). Some studies have also highlighted the role of technological conditions in an industry as a determinant of firm survival (Audretsch, 1991; 1995; Agarwal, 1998), while others have focused on the role of innovative activities, looking at the intensity of R&D expenditure (Hall, 1987; Esteve Perez et al., 2004) and indicators of innovative performance (Cefis and Marsili, 2005 and 2006).

Compared to the few studies on localisation and firm growth, the literature on localisation and firm survival is much richer. Undoubtedly, this reflects the fact that data on firm survival are easier to collect than data on firm growth. However, whereas the little evidence on firm growth seems to point to localization economies, the evidence of such economies on firm survival is rather weak, if not even opposite to the hypothesis that localization entails positive externalities.

Studies comparing different industries typically find evidence for localisation economies only for some industries. For example, Nyström (2007) using a panel data of Swedish firms belonging to 47 different industries shows that localisation affects the firms' exit probability only in 16 out of 26 industries. Similarly, Renski (2010) finds that industrial localisation has positive influence on new firm survival in five out of eight industries that he has examined.

The aforementioned studies by Rosenthal and Strange (2005) and Wennberg and Lindqvist (2010) on firm growth, also found evidence for localisation economies on firm survival. Note, however, that these results can be biased in the sense that only new firms are analysed. Other studies did not analyse localisation economies in terms of own-industry clusters, but agglomeration economies as stemming from knowledge spillovers from any industry (e.g. Stough et al. 1998). Similarly, Raspe and Van Oort (2008) found that a local innovative environment enhances firm survival, which is indicative of knowledge spillovers. However, these findings are contradicted by Brixy and Grotz (2007) who found that German firms had lower survival probabilities in more R&D-intensive regions.

Some recent studies looked at non-linearities in localisation economies. Folta et al. (2006) argued that localization economies are positive, yet turn negative once a cluster grows larger and competition for resources becomes stronger. While Folta et al. (2006) found evidence for this hypothesis for various measures of firm performance, the opposite effect was found for firm exit through bankruptcy. While firm density increased the chances on bankruptcy, the quadratic effect shows that such chances decrease for larger clusters. Similarly, in their analysis of the video game industry, De Vaan et al. (2011b) showed that the negative effects of clustering on firm survival turn to positive effects once a cluster exceeds a critical size.

There are also studies that find neither a positive nor a negative effect of localisation economies. In series of studies looking at firm survival in particular industries, including U.S. car industry (Klepper, 2007), the global fashion design industry (Wenting, 2008), the U.S. tire industry (Buenstorf and Klepper 2009), the U.S. semiconductor industry (Klepper 2010), the German machine tool industry (Buenstorf and Guenther, 2011) and the Dutch publishing industry (Heebels and Boschma, 2011), firms in clusters did not survive longer than firms outside clusters. Importantly, the absence of cluster effects in all these studies becomes apparent only when controlling for pre-entry experience attributed to spinoffs. This means that clusters typically host more successful firms, yet this success does not stem from clustering, but from the experience entrepreneurs have gained working as an employee before they started their firm.

Finally, there are studies that present evidence that clustering is detrimental for firm survival. In their study on the U.S. footwear industry, Sorenson and Audia (2000) found firm density to affect survival negatively. Similarly, Staber (2001) showed that firm density increased business failure rates of knitwear firms in Baden-Wurttemberg, Germany. Stuart and Sorenson (2003) obtained the same result for U.S. biotechnology firms, though in this study other forms of agglomeration economies were found to be survival-enhancing. Looking at services in the U.S., Acs et al. (2007) found for new firms that location in specialised regions is detrimental for survival. Similarly, in a long-term study of the British car industry, Boschma and Wenting (2007) showed that firm density at the time of founding lowered survival rates.

A more subtle approach to the measurement of cluster effects is to distinguish between same-industry and related-industry effects. As many clusters consist of a set of related industries (Porter 1998), one can also analyse whether same-industry concentration and related-industry concentration have different effects on firm survival. One would expect that, while firms may suffer from co-location with close competitors in the same industry, they may profit from co-location with related industries in vertical relations or as sources of cross-sectional knowledge spillovers (Frenken et al. 2007). Indeed, Staber's (2001) analysis of survival of knitwear firms in Baden-Wurttemberg (Germany), showed location in clusters of firms in the same industry increased business failure rates, while location in diversified clusters of firms operating in complementary industries reduced failure rates. Similarly, in a long-term study of the British car industry, Boschma and Wenting (2007) showed that firms had lower survival rates when founded in clusters, but higher survival rates in regions with high levels of employment in related industries. And, in a study on plant survival in Sweden (1970–2004), Neffke et al. (2011a) found no evidence for localization economies, while the local presence of technologically related industries substantially increased survival rates of plants.

In all, despite some studies presenting positive evidence, most studies on clustering and firm survival find little evidence for the Marshallian hypothesis that co-location brings localisation economies. The question that remains is how one can understand that many clusters persist over decades while the firms located in these clusters may not enjoy any benefit or actually suffer from co-location. Probably the most elaborated answer to this question comes from Sorenson in his work on US shoe manufacturing firms (Sorenson and Audia 2000) and US biotechnology firms (Sorenson and Stuart 2003), where he combined entry and exit analysis, He found that, in both industries, local density increased local entry rates. He concluded that the spatial concentration of firms creates opportunities for new entrants by giving them access to 'tacit

knowledge and social ties' (in particular, through spinoffs). This means that areas with large populations of incumbents enjoy a 'regional advantage' in the sense that such areas experience the highest rates of entrepreneurship. Nevertheless, the performance of firms in such clusters is worse than firms outside these clusters reflecting higher levels of competition. Thus, local density promotes entrepreneurship yet worsened the performance of incumbents firms. This led Sorenson to conclude that persistent clustering advantage is not due to agglomeration economies increasing firm performance but due to incumbents shaping opportunities for entrepreneurs.

A final note on the dependent variable in all these studies. Most studies consider survival and the opposite of exit. However, apart from the shutting down of activity and bankruptcy, which are signs of failure, a firm may choose to exit the market by merging with or selling out to others. Indeed, new firms are often created with the explicit objective by entrepreneurs and venture capitalists to sell them to larger firms (Cefis and Marsili, 2007). Thus, exit is not equivalent to failure (Stam et al. 2008; Wennberg et al. 2010). Yet, most studies examining firm exit and survival apply a definition of exit that includes both the actual death of a firm and the exit by merger and acquisition (M&A). This definition often reflects the lack of available data that would allow distinguishing among modes of firm exit. Nevertheless, the ambiguity of the exit used in those studies might cause distortions in the results and may explain, at least to some extent, the divergent results on localisation economies found so far. Weterings and Marsili (2011), using a competing risks model, estimate the effects of cluster location on these two types of exit for Dutch new firms that entered the business services and manufacturing sectors in 1994-1998. They find that cluster location provide new firms with some better chances of survival, but more so, with better options for a potentially successful exit. These benefits, however, coexist, in certain cases, with crowding out effects that set in beyond a threshold of geographic concentration and with increasing competition from the continuous entries of new firms in attractive clusters. Folta et al. (2006) found that – in the US biotech industry - cluster size has a positive, but declining effect on the rate of sell-offs. De Vaan (2011b) looked at the global video game industry and estimated a hazard model both for the probability to exit due to failure and the probability to get acquired. He found that the main determinants that reduced the probability of failure (pre-entry experience and users' quality assessment of the games) were also the main determinants that increased probability of being acquired, underlining the idea that acquisition is a sign of success. Localisation economies only affected failure rates, but did not affect acquisition rates.

3. Lifecycle approaches

Apart from the short-term relationship of clusters on industrial dynamics as discussed before, the long-term interplay between clustering and industrial dynamics has been an object of study as well. Here, the main quest in studies applying a long-term perspective is to understand how clusters emerge and how they evolve over time. Below, we distinguish between three research programmes applying a lifecycle approach to industrial dynamics and economic geography. The *spatial product lifecycle* approach reasons from product life-cycle theory and derives the spatial evolution of an industry from the patterns of innovations that follow from the product's lifecycle (Thomson 1968). Emphasis is on the relocation patterns from core regions to peripheral locations as a product gets standardised and cost competition takes over product competition. The more recent *industry lifecycle* approach explains how entire clusters can emerge from a single successful firm and subsequent spinoffs (Klepper 2007). In this view, localisation economies do not necessarily play any role in the formation of clusters over time. A third body of literature, referred to the *cluster lifecycle* approach, emerged only recently and focuses on the evolution of single clusters (Menzel and Fornahl 2010). The main idea here is that clusters may transform endogenously into structures that become detrimental for the further growth.

All these approaches make use of the lifecycle concept as a biological metaphor. Note that the lifecycle notion has a problematic deterministic flavour as if industries or clusters 'naturally' evolve from one stage

to the next (Martin and Sunley 2011). Rather than viewing lifecycle stages as a pre-determined successions, the concept of a lifecycle is better understood as a heuristic device to organise empirical cases into a coherent framework without denying the indeterminate outcome of processes. For example, in some industries product standardisation does not occur or only at a very late stage (Murmann and Frenken 2006), while in other industries the pattern of industry evolution may actually follow a reverse lifecycle as it has been argued for service industries (Barras 1986). For single clusters, the idea that its development necessarily follows particular stages is even less appropriate. Rather, as Menzel and Fornahl (2010) argued, clusters renew themselves typically by various forms of upgrading, thus switching back to an earlier stage of the cluster lifecycle. Allowing for such pattern of re-adjustment, the lifecycle notion looses its problematic deterministic connotation, while still conserving its heuristic value.

3.1 Product lifecycle approach

The product lifecycle is among the most long-lived concepts in industrial dynamics dating back to the seminal work by Vernon (1966) in the field of international trade and Utterback and Abernathy (1975) in the field of innovation studies. The notion of a lifecycle suggests that industries typically evolve in particular stages. In the explorative stage of an industry, entrepreneurs exploit the commercial opportunities of a new product by means of product innovation. At this stage, firms poorly understand technological possibilities and preferences of consumers. Progressive standardisation in product design subsequently triggers process innovation. This marks the transition from the explorative stage to the mature stage of the product lifecycle. The mature stage finally ends when all technological and market opportunities become depleted and decreasing returns to R&D set in.

The patterns of innovative activity bear important consequences for the industrial dynamics. Initially, many firms enter in an attempt to exploit the opportunities provided by the new product. Over the product life cycle, firms learn how to scale their production and consequently raise the entry barriers for newcomers. Scaling is further facilitated by the mergence of industry wide product standards otherwise known as ‘dominant designs’ (Abernathy and Utterback 1978). Such standards lower product innovation and trigger process innovation. As a result, higher entry barriers limit further entry, and price competition forces less efficient firms to exit. This “shake-out” phenomenon leads to a rapid fall in the number of participating firms, and the industry is transformed in a highly concentrated one (Klepper 1996).

There have been various attempts to systematically test the product lifecycle model through the analysis of data on innovation and industrial dynamics (see Murmann and Frenken 2006, for an extensive overview). Two main studies are worth mentioning. An extensive study by Gort and Klepper (1982) on the product lifecycle dynamics of no less than 42 products found that net entry first rises and than falls, while entry is also positively correlated with the rate of innovation in agreement with the product life-cycle model. In a later study, Utterback and Suarez (1993) went through studies on the history of eight technologies and found dominant designs to have emerged in six industries. In these industries, a rapid rise in the number of firms is observed before standardisation took place, and a sudden fall in the number of firms, hereafter. For the two technologies for which no standardisation was observed, the number of firms did not fall rapidly.

The geographical implications of the product lifecycle have received attention in economic geography for long (Thomson 1968; Markusen 1985; Davelaar 1991; Duranton and Puga 2001). Yet, studies have been less systematic and comprehensive than aforementioned studies. The main hypothesis holds that industries at an early stage in their lifecycle are expected to be overrepresented in metropolitan core areas, while mature industries are expected to be overrepresented in peripheral areas. Firms in an emerging industry will be located more often in metropolitan areas where venture capital, talent, early users and supporting institutions are more abundant. These factors provide the best breeding ground for product innovations. Mature industries with larger firms will disperse and locate more often in smaller towns in

peripheral areas as to benefit from low wages, lower land prices and less stringent environmental regulations. In such environments, firms can more easily scale-up their operations by process innovation. As an industry moves from its explorative stage to its mature stage in its lifecycle, the dominant location of an industry is also expected to move from core to periphery (while the reverse may take place when an industry de-matures). Thus, the product lifecycle theory predicts relocation patterns to be predominantly from core to periphery.[4]

An additional explanation for the expected spatial lifecycle pattern is based on agglomeration economies and holds that metropolitan core areas are attractive for small innovative firms active in the explorative stage of the product lifecycle due to the high density of other innovative firms generating knowledge spillovers, specialised supporting services and opportunities for collaboration (Audretsch and Feldman 1996). With the product still being in development, inter-industry spillovers[5] are relatively important as provided by the diversified nature of the core's economy (Henderson et al. 1995; Duranton and Puga 2001). Thus, the many small firms active in the early stage of a product lifecycle benefit most from the agglomeration economies generated in the core. Larger firms in mature industries, by contrast, rely more on in-house R&D aimed at process innovation and, therefore, would benefit less from being located in core metropolitan areas. And with the product being standardised and stable value chains being created, intra-industry spillovers[6] (and intra-firm economies) become more important as provided in specialised clusters outside the core (Henderson et al. 1995).

There is a wide variety of empirical studies informed by the spatial product lifecycle. Most early studies concentrated on the spatial differentiation of innovation patterns. Here, the product lifecycle thesis predicts that core areas are more innovative than peripheral areas, and that product innovation is overrepresented in the core, while process innovation is expected to be relatively dominant in the periphery. In general, innovation scales non-linearly with city size. A patent study on U.S. cities showed that the number of patents per capita in a city increase with city size (Bettencourt et al. 2007). An earlier study based on a UK survey (1980) found that both large and small establishments in the UK's core area (South-East Region) were indeed more innovative than those located in other regions (Oakey et al. 1980). The authors attributed these differences primarily to the levels of non-production employment in each region rather than by plant size structure or regional industrial structure. In contrast, Davelaar and Nijkamp (1989) and Kleinknecht and Poot (1992) did not find the Netherlands's core to be more innovative than the periphery. Yet, and in line with product lifecycle theory, firms in the periphery had relatively higher shares of process innovation than firms in the core. This finding has also been confirmed in a follow-up study on Dutch firms (Brouwer et al. 1999).

Other studies were based on longitudinal data as to verify the process of spatial deconcentration and firm relocation. The study by Markusen (1985) and a follow-up study by Sorenson (1997) both looked at dispersion patterns for a small number of U.S manufacturing industries, for the periods 1954-1977 and 1954-1987, respectively. They both found that the predicted pattern of increasing spatial dispersion over the product lifecycle could only be validated in a limited number of industries. Similarly, using patent data for the period 1987-1991, Breschi (2000) found that traditional industries like clothing, furniture, agriculture and sports & toys display a pattern of increasing spatial dispersion, while 'science-based' industries like chemical industries and electronics remain highly concentrated. In a more recent study using employment data for French cities, Pumain et al. (2006) found that during the period 1960-2000 electronics, chemicals, textiles, metal products, machinery and equipment, and wood, pulp & paper industries all progressively relocated from the metropolitan cities to smaller cities. At the same time,

[4] A similar reasoning underpins international trade theory in which the location of an industry is expected to move from high-wage economies to low-wage economies over its product lifecycle (Vernon 1966).
[5] Otherwise known as Jacobs externalities.
[6] Otherwise known as Marshall-Arrow-Romer (MAR) externalities.

metropolitan cities became increasingly specialised in R&D over the period considered. Similarly, Duranton and Puga (2001) found that most French firms relocate from an area with above median diversity (typically the large metropolitan areas) to an area with above median specialization in the corresponding sector (typically the smaller cities). They also found that high-tech industries have a much higher share of relocations than mature sectors. In a study on Portuguese firms, Holl (2004) also found that start-ups are attracted by large diversified cities. Relocating firms, by contrast, were more attracted to location with a specialized industrial base and good highway accessibility. In a study on relocating firms in The Netherlands, Pellenbarg and Van Steen (2003) found that most inter-regional relocations concern firms leaving the metropolitan core. For all these studies, the relocation patterns observed are consistent with the spatial product lifecycle theory.

A third strand of empirical research looked at the role of agglomeration economies in new industries versus mature industries. The reasoning underlying this literature holds that new industries benefit mostly from inter-industry spillovers and therefore locate in core metropolitan areas with a variety of industries (Jacobs externalities), while mature industries based on standardised products profit more from intra-industry spillovers in smaller, specialised cities. This also implies that relocating firms do so from the core area to a specialised location outside the core. Evidence for such patterns were indeed found in a study by Henderson et al. (1995) analysing the growth of eight manufacturing industries in U.S. cities. They found that new industries prosper in large diversified metropolitan areas while mature industries profit from being located in specialised cities. In line with this evidence, Neffke et al. (2011c) used a Swedish plant level dataset that covers the period of 1974-2004 and showed that the benefits industries derive from their local environment are strongly associated with their stage in the product life cycle. Whereas localisation economies increase with the maturity of industries, Jacobs externalities decline when industries are more mature. And, using a comprehensive database on Dutch firms of all sizes and all sectors, Capasso et al. (2010) found that entry and exit rates are indeed highest in the core and lowest in the periphery, even if differences are small. Interestingly, these patterns are largely robust for service sectors as well. They also found that ICT-related industries, as emerging industries, tend to be over-represented in the core or semi-periphery, while Fordist industries, as mature industries, found to be over-represented in the periphery. Thus, the location patterns of innovative and mature sectors can be understood well in the light of the spatial product lifecycle.[7]

A related concept to probe industry differences in entrepreneurship rates has been the concept of technological regime (Winter 1984; Marsili 2001). The basic idea underlying the notion of technological regime holds that industries are typically characterised either by an entrepreneurial regime with high technological uncertainty, many small firms and high rates of entry and exit (often in the emerging stage of a product lifecycle) or a routinized regime with low technological uncertainty, dominant incumbents and low rates of entry and exit (often in the mature stage of a product lifecycle). In a large-scale empirical study using data on 49 technology classes, Malerba and Orsenigo (1996) indeed found that the industrial dynamics in most of these classes correspond closely to one out of the two regimes. In a follow-up study, Breschi et al. (2000) attributed these differences in industrial dynamics to differences in technological regimes. They found that the first regime was characterised by high technological opportunities, a low degree of cumulativeness and appropriability, and an applied-science base, and the second regime

[7] Note that the spatial lifecycle thesis predicts that the urban core, once formed, can continue to renew itself due to the advantages it created for product innovation and new industry formation (cf. Hall 1998; Glaeser 2005). However, historically, there have been cases of cores shifting, famously, in the United States from the 'Manufacturing Belt' to the 'Sunbelt' (Rees 1979) and in Belgium from the Walloon area to Flanders (Boschma 1997). In both cases, the locus of product innovation and new industry formation shifted from one region to another, shifting what is to be considered to be the economic core of a country. These more fundamental shifts have been associated these fundamental shifts with Kondratieff's waves leading to new techno-economic paradigms (Freeman and Perez 1988).

characterised by low technological opportunities, a high degree of cumulativeness and appropriability, and basic-science base.

Building on the concept of technological regime, Audretsch and Fritsch (2002) introduced the concept of regional growth regimes. Here, different regimes of industrial dynamics (high or low entry rates) are associated with different outcomes on regional employment growth. A regional growth regime is called *entrepreneurial* if employment is high and results primarily from new firm start-ups, while a regional growth regime is called *routinized* when growth is relatively more driven by large incumbent enterprises. They add to this taxonomy two other types of regions: *revolving-door* growth regimes with many start-ups but low employment growth reflecting entries being non-innovative, and those regions with low employment growth and *downsizing* growth regimes dominated by incumbents that relocate production to (foreign) sites with lower input costs. For no less than 20 regions, the routinized or revolving door regime was observed, highlighting that high entry rates are neither a necessary nor a sufficient condition for regional employment growth.

3.2 Industry lifecycle approach

Contrary to product lifecycle research, industry lifecycle studies analyse industry evolution purely in terms of the underlying industrial dynamics of entry and exit of firms competing in a particular product-market, i.e. an industry. The dynamics of innovation is not assumed to follow a certain pattern that is exogenous to firm behaviour. Rather, the product lifecycle pattern of product innovation preceding process innovation can be logically explained by firm incentives: product innovation has a higher return for smaller firms than for larger firms, while the opposite holds for process innovation (Klepper 1996). In contrast to product life cycle research, industry life cycle research explicitly takes the nature, especially the capabilities, of the firm as a key variable to be explained and as *explanans* for industry evolution (Klepper 2002).

Following a demographic logic, these studies describe industry evolution by the number of firms active in an industry at each moment in time, which equals the cumulative number of entries minus the cumulative number of exits. The spatial evolution of an industry can then simply analysed by the spatial distribution of firms across regions. Here, the number of firms in a region at a particular moment in time equals the cumulative number of entries and inward migrating firms minus the cumulative number of exits and outward migrating firms.

The dynamics of spatial clustering follow from the location decisions of new entrants and the quality of their capabilities. New entrants most often have experience in the same or related industry. Following Klepper (2002), one may call firms diversifying from a related industry ‘experienced firms’ and entrepreneurs who set up a firm and previously worked as an employee in a related industry ‘experienced entrepreneurs’. Since these firms inherit relevant capabilities from a related industry, they possess pre-entry experience. However, spinoffs possess even more relevant pre-entry experience, as the employees who set up spinoffs firms have previously worked in exactly the same industry. Obviously, during the emergence of an industry, spinoffs do not exist, as potential parent firms are not yet active in the industry. That is why the first generation of entrants is typically composed of experienced firms and experienced entrepreneurs, and, occasionally, *de novo* start-ups without any relevant pre-entry experience. Over time, the share of spinoffs increases at the expense of other types of entrant. This pattern can be understood from the increasing entry barriers created by successfully growing incumbent firms. Since spinoffs have the most pre-entry experience, only these firms can overcome the entry barriers and compete with incumbents.

The dynamics of spatial clustering can now be understood as follows (Klepper 2007; Buenstorf and Klepper 2009). Firms are assumed to be heterogeneous in their capabilities, partly because of different

pre-entry experience and partly because of idiosyncratic factors. The firms with capabilities that happen to fit best market demand and technological supply factors will grow fastest and produce most spinoff firms. Spinoffs inherit a large part of the capabilities of their parent, which explains why successful firms tend to create successful spinoffs. Thus, following a Darwinian logic (Boschma and Frenken 2003), more successful firms produce more, and more successful, spinoffs. Since spinoffs tend to locate in the same region as the parent firm (Dahl and Sorenson 2009) a cluster emerges once a few successful firms start to create many successful spinoffs which, in turn, create successful spinoffs themselves. Once exit rates start to increase to due rising competition levels stemming from increasing economies of scale at the firm level, these firms will survive while firms with less fit capabilities will have to exit. As a result, a cluster emerges in the region(s) where the initial successful parent(s) happen to have located in the past.

Indeed, Klepper (2007) could explain the emergence of the Detroit automobile cluster by interacting the spinoff and the Detroit variables, showing that spinoffs within the Detroit cluster outperformed spinoffs outside the cluster. The emergence of the Detroit cluster, then, can be attributed to the exceptional capabilities of Detroit spinoffs inherited from selected parents in Detroit. This methodology was also used in the studies on US tire firms clustering in Akron, Ohio (Buenstorf and Klepper, 2009) and Dutch publishing firms clustering in Amsterdam (Heebels and Boschma, 2011). In both cases, it was also found that spinoffs within the cluster outperformed spinoffs outside the cluster, suggesting that clusters emerged through the transmission of exceptionally fit capabilities from selected parent firms within the cluster. The success of a cluster, then, can be traced back to a single, or few successful parent firms that pass on their capabilities to several generations of spinoffs firms. It also means that clusters are expected to emerge even in the absence of localisation economies. Indeed, once controlling for pre-entry experience, Klepper (2007) showed that Detroit firms did not have higher survival rates than firms outside Detroit. Other studies applying the industry lifecycle framework came to the same conclusion. In the UK car industry (Boschma and Wenting, 2007), the global fashion industry (Wenting, 2008), the US tire industry (Buenstorf and Klepper, 2009), the US semiconductor industry (Klepper 2010), the German machine tool industry (Buenstorf and Guenther, 2011), the Dutch publishing industry (Heebels and Boschma, 2011), being located in a cluster did *not* increase the survival probability of firms. Only for the global video game industry, positive location economies were identified once a cluster grew passed a critical size (De Vaan et al. 2011b).[8]

This industry lifecycle model and its spatial implications explains why there is regional path dependence (Martin and Sunley 2006): since the first generation of firms are not composed of spinoffs, but mostly by experienced firms and experienced entrepreneurs coming from related industries, regions that host industries that are related to the new industry, have a higher probability to create this new industry. However, regional success in one industry is not automatically reproduced in the next industry, as the success of firms is only partly determined by pre-entry experience. As new industries also rely on newly created knowledge, the 'Windows of Locational Opportunity' are open, at least to some extent, for any region (Storper and Walker 1989; Boschma 1997). Yet, regions hosting related industries clearly enjoy an advantage, because related industries provide a large pool of potential experienced firms and experienced entrepreneurs. So the emergence of new industries over space is on the one hand largely a chance event, but chance favours the prepared region, i.e. regions with an industry and knowledge structure that is related to the emerging industry (Feldman and Francis 2003).

3.3 Cluster lifecycle approach

[8] It should be noted, however, that in some industries clusters do not emerge despite the fact that spinoff firms were pervasive. Notably, only low degree of spatial concentration has been observed in the US laser industry (Klepper and Sleeper 2005) and German laser industry (Buenstorf and Geissler 2010). This 'anomaly' has been attributed to the presence of many submarkets in the laser industry, which limited competition among these markets, leaving room for many firms to survive in niches.

Rather than looking at the development of an industry as a whole, one can also ask the question how single clusters develop over time, where a cluster here refers to a geographical concentration of firms operating in the same or related industry. To some extent, the growth of clusters will be correlated to the growth of the industry as a whole. Once a new industry emerges, many new clusters tend to emerge, while clusters generally suffer once an industry gets into decline. However, the whole notion of cluster lifecycles is based the idea that, even if industrial and cluster evolution are correlated statistically, they cannot be equated (Menzel and Fornahl 2010). For example, a cluster may decline while an industry is still growing, for example, if a lead firm relocates or a high-wage cluster faces competition from low-wage countries. And, *vice versa*, a cluster may continue to grow despite the decline of an industry, for example, by specialising in high-end components or by diversifying into other industries. Therefore, cluster evolution is a separate object of study.

Following some of the early seminal studies on declining clusters by Glasmeier (1991) on watch-making in the Swiss Jura region and Grabher (1993) on steel and coal industries in the Ruhr area, as well as on emerging clusters in ICT sector including and Cambridge (Keeble et al. 1989), Silicon Valley (Saxenian 1994), Sophia Antipolis (Longhi 1999), interest in the evolution of clusters has grown rapidly only recently as evidenced by various book volumes (Curzio and Fortis 2002; Breshnahan and Gambardella 2004; Fuchs and Shapira 2005; Braunerhjelm and Feldman 2006; Fornahl et al. 2010). At the same time, systematic studies documenting the industrial dynamics of particular clusters over long periods of time has remained scarce (e.g., Garnsey 2007), as such data cannot be collected with official statistics. Therefore, the exact role of industrial dynamics and localisation economies in the lifecycle evolution of single clusters has been probed primarily conceptually while building on the increasing case study evidence at hand. It is beyond the scope of this review to discuss all the different case studies. Rather, we will discuss the various conceptual frameworks of cluster lifecycles that have been proposed with reference to illustrative case studies.

Reasoning from localisation economies, cluster development can be explained in the most elementary way as an ecological process (Swann 1997; Maggioni 2002). Following the evidence discussed on entry, entry rates are expected to increase with cluster size. The positive association between cluster size and entry rates may reflect localisation economies, but no necessarily so (Buenstorf and Klepper 2009; Buenstorf and Geissler 2011). A simpler explanation would to assume that each firm has an equal probability to generate a spinoff firm. This means that the probability that a spinoff occurs in a region is proportional to the share of firms located in that region. As a result, even when starting from a uniform distribution, some regions are more likely to generate a cluster than other regions, which are most likely to remain underdeveloped (Arthur 1994; Boschma and Frenken 2003).[9] This process continues until a cluster reaches a size that the increased competition among cluster participants leads to increased exit rates.

Note that cluster growth is bounded not only by increasing competition levels, but also by economy-wide agglomeration diseconomies such as to increasing congestion, pollution, and factor prices. A typical example of such constraints on further growth has been the Cambridge region, where housing prices have risen much more rapidly than the UK average during the growth of the local high-tech economy (Stam and Martin 2011). Cluster growth will also depend on favourable institutional settings, both pre-existing and both constructed along the lifecycle of the cluster through collective action (Boschma 1997). For example, the viability of a cluster depends on its ability to develop technical standards that are globally accepted (Vicente and Suire 2007; Vicente et al. 2011). Other favourable institutions that stimulate further

[9] More generally, such a null-model can be used to explain urban growth and corporate growth in a single framework following Simon's model (1955) of proportional growth. See, Frenken and Boschma (2007) for such a framework.

cluster growth include training and research institutions, specialised infrastructure, regional branding, and funding schemes for new firm formation and cooperation. A typical example is the Sophia Antipolis research park. After an initial 'exogenous' growth phase, university departments relocated to the park and government schemes were set up to promote collaboration, leading to an endogenous growth pattern (Quéré 2007). Since these institutions are both the product and the cause (of subsequent) cluster development, explanations of successful clusters based solely on institutions are, therefore, questionable. Rather, the question is how different regions cope with institutional change by creating institutions supportive of cluster development and abolishing institutions that constrain cluster progress (Boschma and Frenken 2009; Sine and Lee 2009).

To the extent that firms at different locations compete for the same clients or resources, the exact size of a single cluster will also depend on competition levels between firms in different clusters. Clusters that start growing at an early stage will face little competition from firms elsewhere, while clusters that start growing at a later stage will face stronger outside-cluster competition. This model would predict that clusters that start growing early on, for example due to some exogenous 'historical event', will also come to dominate the industry. Empirically, however, this logic of first mover advantage does not necessarily hold. For example, Detroit grew out to be the single dominant cluster in the U.S. automobile industry, yet it hosted no single firm in the first seven years of the industry (Klepper 2007). To explain this more complex patterns, one can assume that firms are heterogeneous in their organizational capabilities from which it follows that some firms will grow much faster than others, and will produce more, and more successful, spinoffs than others. Latecomer regions can still develop a cluster provided that they host one or more firms with outstanding organizational capabilities (Klepper 2007).

Complex growth patterns of clusters may also be related to hypes due to herding behaviour in location decisions. Suire and Vicente (2009) developed a model of cluster emergence and stability that also takes into account herding effects (also known as informational cascades). Firms may locate in clusters not for alleged localisation economies associated with co-location, but for legitimation reasons only or what Appold (2005) called 'geographical charisma'. Some clusters have a strong reputation due to visible successful firms that attracts other firms to locate or relocate to such clusters as to signal to their stakeholders that they are present 'where the action takes place' (for example, Google in Silicon Valley). The model by Suire and Vicente (2009) shows that if legitimation effects prevail, a cluster can grow very fast, but remains fragile as the pattern of co-location is not based on complementarities or economies created by the co-locating. Once the reputed firm would loose its reputation, or would relocate to another location, the cluster is likely to break down. An example of a cluster that emerges quickly but failed to stabilise is the dotcom-cluster of Silicon Sentier in Paris, where Yahoo as a reputed company attracted many firms, but which broke down after the dotcom bust (Dalla Pria and Vicente 2006). An older example of a cluster that initially emerged through herding is the Sophia Antipolis research park with IBM and Texas Instruments as triggers. Contrary to Silicon Sentier, however, this cluster survived the 2001 recession as employees became socially embedded in the region leading to local spinoffs from relocating firms (Quéré 2007) and local inter-firm collaboration increasing rapidly over time (Ter Wal 2011).

The most comprehensive framework of cluster lifecycle so far has been proposed Menzel and Fornahl (2010) building on prior arguments by Grabher (1993) and Pouder and St. John (1996). Their theory is centred on the evolutionary concept of heterogeneity among firms' capabilities. They illustrate their theory as in figure 1. In this figure, the level of heterogeneity is mapped onto the lifecycle stage of cluster development. As the cluster emerges, heterogeneity initially increases because every new company entering the cluster tends to add to heterogeneity given the varied pre-entry backgrounds. As the cluster further grows and develops, heterogeneity subsequently decreases as more firms share pre-entry experience at the same parent (Menzel 2005), collective development of technical standards (Vicente and Suire 2007) and other kinds of process of inter-firm learning (Menzel and Fornahl 2010). On the one

hand, this convergence enables clustered firms to mutually utilize external knowledge more easily than non-clustered firms. On the other hand, however, if this process of convergence continues, competition among cluster firms further increases and the recombinant innovative potential of the cluster decreases. A related notion is the concept of related variety stressing that variety provides sources of knowledge spillovers provided that this variety can be recombined (Frenken et al. 2007).

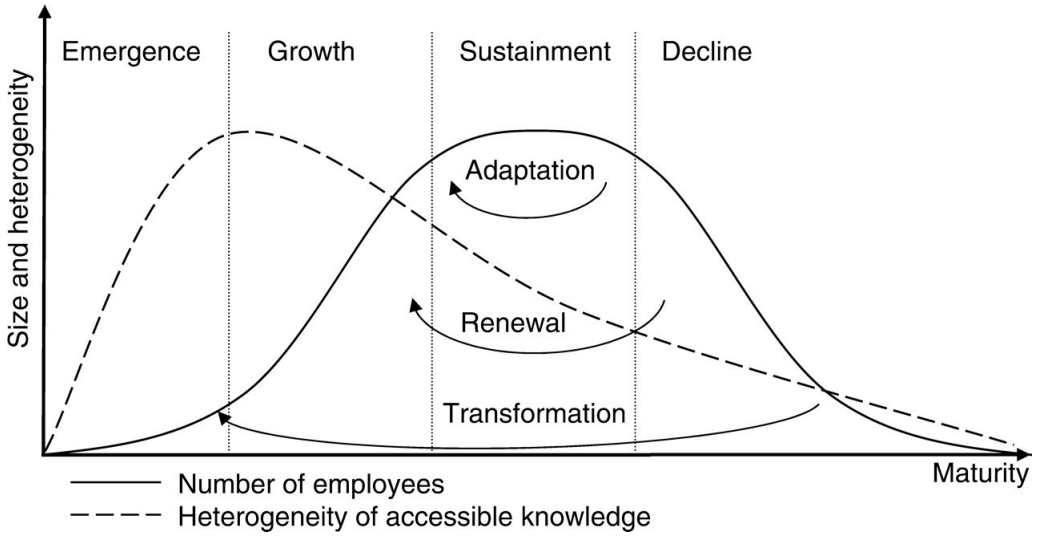

Figure 1. Cluster lifecycle dynamics
(source: Menzel and Fornahl, 2010, p.218)

Note, however, that decline in this model results from the endogenous process in which firm heterogeneity declines, while in other cases clusters may decline due to external shocks, for example when a new technological paradigm emerges. The famous example of such a cluster decline is the Swiss Jura region that lost its leading position once quartz was introduced into watches (Glasmeier 1991). Also in cases of exogenous shocks, firms may have difficulties to adapt given the lack of heterogeneity in the cluster. That is, heterogeneity adds to a cluster's 'resilience' in the face of global uncertainties in technological development, world prices and macro-economic conditions (Hassink 2010; Pike et al. 2010).

Menzel and Fornahl (2010) argue that a declining cluster can start to grow again (i.e. move "back" in the cycle as in Figure 1) by increasing its heterogeneity of knowledge sources. For example, a cluster can upgrade its existing technology base by sourcing state-of-the-art knowledge from outside the cluster. Hereafter, a cluster can grow again by competing on quality or cost competitiveness. The authors call such an incremental process adaptation. Clusters can also renew themselves by integrating new technologies, as happened with the integration of ICTs in many existing industries. Menzel and Fornahl (2010) speak of renewal in this case. Such strategies extend the life of a cluster without affecting its core knowledge base and core markets. In many cases, as exemplified by figure 1, such a strategy may only help in the short-term. For example, Hassink (2011) discusses the evolution of four clusters and concludes that such short-term strategies did not lead to structural increases in competitiveness.

The most radical form of adjustment takes place when a cluster developed whole new industries, typically building on the knowledge bases built up in the past. This evolutionary process of related diversification

has also been referred to as a process of regional branching (Boschma and Frenken 2011). For example, Tappi (2005) illustrates how the accordion cluster in Marche (Italy) moved into electronics and how the new knowledge was brought into the cluster by expatriates from Marche who had lived in the US. Other examples include the television industry that branched out from the radio sector in the US (Klepper 2006) and the environmental sector emerging out of the coal and steel sectors in the Ruhr area (Grabher 1993).

In a more systematic study on the economic evolution of 70 Swedish regions during the period 1969-2002, Neffke et al. (2011b) showed that industries that were technologically related to pre-existing industries in a region had a higher probability to enter the region, as compared to unrelated industries. Furthermore, they show that unrelated industries had a higher probability to exit the region. This pattern suggests that regional development is greatly affected by its industrial past with clusters typically diversifying into related industries. That is, there a strong regional path dependence in long-term regional development.

Boschma and Frenken (2010) and Ter Wal and Boschma (2011) have developed a framework of cluster evolution similar to that of Menzel and Fornahl (2010), but with a focus on how market structure, networks and clusters co-evolve. From the industry lifecycle model, it is known that – at least for most manufacturing industries - the number of firms first grows rapidly, then falls rapidly again ('shake-out'), and eventually stabilizes into an oligopolistic market structure dominated by a few persistent industry leaders (Klepper 1997). One can further assume that, to the extent that formal and informal networking contributes to firm survival, surviving firms typically have extended network relations. Since network relations are often geographically localised, one expects the network density in clusters to increase over time.

As the number of firms falls over time, the remaining firms are typically embedded in strong social networks and interlocking corporate boards, which tend to resist structural change in the face of a crisis. Such resistance can be reinforced by increasing organisational proximity between firms by production networks or mutual financial participation between cluster firms (Glasmeier 1991; Grabher 1993) as well as by higher levels of cognitive proximity between cluster firms resulting from the interactions in the past (Pouder and St. John 1996; Menzel and Fornahl 2010). According to Grabher (1993) and Hassink (2005), such structures typically explain the inabilities of old industrial regions to successfully renew themselves. The solution to such 'regional lock-in' phenomenon clearly lies in trying to re-organise network relations such that interactions can take place between clusters actors that are less proximate in social, cognitive and organizational dimensions. This could be accomplished by the formation of new ties that bridge unconnected networks (Grabher and Stark 1997). Furthermore, firms in locked-in clusters may invest in long-distance networks. Such relationships are facilitated in case the knowledge base of an industry has been progressively codified, as shown in the case of German inventor networks in biotechnology (Ter Wal 2009).

4. Summary and conclusions

We started to define the field of industrial dynamics in a narrow sense as the study of entry, growth and exit of firms across industries. The interface with the discipline of economic geography that we derived from this definition lead us to formulate as the central question how clusters of economic activity can be understood from the entry, growth and exit of firms, and how, in turn, clusters affect entry, growth and exit patterns through localisation economies. We answered this question by reviewing in section 2 how clusters affect entry, exit and growth through localisation economies (as part of agglomeration economies generally), and in section 3 how entry, growth and exit patterns lead to spatial clustering and cluster dynamics focusing on lifecycles perspective.

The first conclusion we could draw holds that clustering has a strong effect on entry. Without exception, empirical studies found that entry rates increase with cluster size. Importantly, this empirical association does not in itself indicate that firms locate in cluster because they benefit from co-location, since most potential entrepreneurs simply locate in clusters because they originate from the same region. This does not hold for the location choices of subsidiaries, for example, in the case of foreign greenfield investment. For these studies, localisation economies seem to play a role in entry decisions, but only for technologically lagging firms who have most to gain and least to loose from co-location (Shaver and Flyer 2000; Alcácer and Chung 2007).

The second main conclusion holds that there is only weak evidence that localisation contributes to firm performance. The evidence supporting the hypothesis of localisation economies seem to hold in studies looking at young firms, while studies covering firm of all ages generally find no evidence or even negative evidence for this hypothesis. One can argue that given the heterogeneity in capabilities between young and more established firms, young firms may profit more from co-location than older firms. Such an explanation, which remains to be tested more systematically, is in line with recent work on plant-level productivity by Brown and Rigby (2010) who showed that relatively new plants benefit the more from localisation economies than older plants in the Canadian manufacturing sector.

A third finding concerns the role of related industries for firm performance. Even if firms do not necessarily benefit from co-location with firms that are active in exactly the same industry, a number of studies show that co-location with firms active in related industries is beneficial for firms. This finding indicates that firms may experience negative externalities from co-location with same-industry firms due to involuntary knowledge spillovers and competition for critical resources such as talented employees, while they may experience positive externalities from co-location with related-industry firms as knowledge spillovers then occur to non-competing firms (Staber 2001).

Conclusions regarding the various lifecycle perspectives on where clusters emerge and how they evolve are necessarily less systematic, since research designs and data used are much less standardised compared to studies testing the effect of clustering on entry, growth and exit rates. Nevertheless, the available evidence is largely consistent with predicted patterns.

Concerning the spatial product lifecycle, the main hypothesis holds that emerging innovative industries profit most from being located in large diversified cities while mature routinized industries tend to locate in smaller specialised cities. Indeed, the available evidence suggests that localisation economies increase with the maturity of industries, while benefits from variety tend to decline when industries become more mature. Furthermore, work on firm relocation shows that the dominant pattern is from larger cities to smaller towns, indicative of firms that look for locations with lower prices for inputs as their technologies become standardised and competition shifts from product competition to cost competition.

Evidence on the more recent *industry lifecycle* theory and its emphasis on spinoffs dynamics as the main driver underlying cluster formation, is also quite consistent. All studies find that spinoffs outperform other firms and that localisation economies have no effect on firm survival. Only for one specific industry (video game industry), positive location economies were identified once a cluster grew beyond a critical size. The industry lifecycle model explains why there is regional path dependence: since the first generation of entrants are not composed of spinoffs, but mostly by firms set up by people with experience in related industries, regions that host industries that are related to the new industry, have a higher probability to create this new industry. Thus, even though the location of new industries can be sensitive to the random location of exceptional entrepreneurs that bring forth many generation of spinoffs, chance stills favours the prepared region in that regions with clusters related to the emerging industry will have a much higher probability to create clusters in new industries as well.

Finally, work on cluster lifecycles has analysed the industrial dynamics of single clusters in terms of the number and size of firms, entry and exit patterns, their relations and complementarities, and the wider institutional context. Notwithstanding the important contributions in this field of study over the past decade, the empirical basis is still primarily limited to case studies. These studies provide illustrative evidence of different pathways a cluster can follow, ranging from decline, adaptation, renewal, to complete transformation. Yet, to further understand the industrial dynamics underlying cluster lifecycles and to test the validity of various theoretical frameworks that have been proposed, more systematic data collection is needed on the entry, growth and exit of firms as well as on their individual knowledge bases and their network interactions.

5. Further research

From the review, one can list a number of suggestions for future research that would lead to important refinements in theoretical frameworks, research design and empirical validity. The main challenge in future research lies in settling contradictory empirical findings. In particular, from our review it has become clear that the main gap in our empirical understanding concerns the effect of localization economies on firm performance, which some may even consider the key question in economic geography at large. There are two parallel strategies that can be followed, one theoretical and one methodological, which are preferably combined in practice.

Regarding theory, the conflicting results on localization economies may be due to fallacies in our reasoning. In particular, the common assumption that all firms equally profit from co-location seems ill-founded. From an evolutionary economic perspective, a starting point in any analysis should be that firms are heterogeneous in their organizational routines and hence, in their capabilities (Nelson and Winter 1982; Boschma and Frenken 2006). One hypothesis that follows holds that the less developed a firm's capabilities, the more it might potentially gain from being located in a cluster (Brown and Rigby 2010). One could develop a more refined hypothesis arguing that the relationship is bell-shaped, with firms with intermediate levels of capabilities profiting most from clustering as some minimum capabilities to be able to absorb knowledge from nearby firms are necessary (Pe'er et al. 2008; cf. Cohen and Levinthal 1989). Reversely, one could argue that firms with the most advanced capabilities have most to loose to competing firms in a cluster (Shaver and Flyer 2000), unless these are difficult and costly to learn by others (Alcácer and Chung 2010). Further analysis can also be done on the decomposition of localization economies into its three Marshallian components of specialized suppliers, thick labour markets and knowledge spillovers (e.g., Brown and Rigby 2010; Alcácer and Chung 2010). For example, one expects lagging firms to profit more from knowledge spillovers than larger firms, while larger firms may benefit more from specialized suppliers and employees. In short, further theorizing about cluster benefits should start from a theory of the firm that highlights firm heterogeneity and the role of external learning. From this, various hypotheses can then be developed that may account for the conflicting results obtained so far.

Regarding methodology, the empirical definition of clusters remains an unsettled issue that few authors explicitly address. Rather, most studies selectively follow from some common practice leading to persistent inconsistencies in the operational definition of clusters. A better understanding of localization economies would necessitate a higher degree of methodological standardization (Wennberg and Lundquist 2010). A series of operational issues can be addressed in this context. First and foremost, the current use of various indicators of localization economies (including location quotients, same-sector employment, cluster dummies, number of same-sector firms) is undesirable. Since we deal with externalities stemming from co-location of firms, the simple measure of the absolute number of firms seems most desirable (and, in fact, is most common). If possible, a more direct measurement of the alleged mechanisms underlying knowledge spillovers is preferable. For example, networks have been

shown to be an important vehicle of knowledge spillovers (Breschi and Lissoni 2009; Ponds et al. 2010). Second, the industry definition is often taken from official statistics, while these generally do not capture relevant product-markets. Thus, categorizations based on product data are thus to be preferred (Neffke et al. 2011a, 2011b, 2011c). Furthermore, as most cluster definitions include related industries in the delineation of a cluster, the definition of a related industry is also important. Recent work on relatedness makes use of labour mobility flows as to indicate the skill-relatedness between industries, arguably the most relevant dimension in localization economies (Neffke and Henning 2009). Finally, our review highlighted the importance of differentiating between different modes of entry (de novo, spinoff, subsidiary) and different modes of exit (bankruptcy, voluntary, acquisition). The effect of clusters on these different types of firms has been shown to be substantial and sometimes even opposite.

Another fundamental methodological problem remains the definition of the relevant geographical boundaries of clusters. Such boundaries may well be different for different mechanisms underlying localization externalities (Rosenthal and Strange 2001; Wennberg and Lundquist 2010). Local labour market areas seem to be the obvious level of spatial aggregation as to capture the Marshallian benefits of specialized labour. Similarly, one can argue that local labour market are also the main level at which knowledge spillovers occur, as such spillovers often stem from employees' social networks in the local area (Breschi and Lissoni, 2009), though some have argued that such spillovers are likely to occur primarily at even smaller distances (Rosenthal and Strange 2001), or longer distances (Botazzi and Peri 2003; Woodward et al. 2006). For what regards specialized suppliers, the relevant spatial level is more dependent on the specific industry. In most industries, the relevant spatial area is arguably much larger than local labour markets, except for industries that are characterised by time-sensitive production processes.

Further challenges lie in the field of industrial dynamics defined in the broader sense, including the role of demand, networks and institutions (Malerba 2007). Such topics are obviously even more complex than those addressed above, and may require a different type of framework and methodology. One promising apporach in this respect in the 'Sectoral Systems of Innovation' approach, which explicitly links industrial dynamics to differences in technological regimes, demand conditions and sector-specific institutions (Malerba 2002; Oltra 2009). Another framework building on the theory of dynamic capabilities and addressing national differences in innovation and industrial dynamics is the approach of 'Varieties of Capitalism' and its core concept of institutional complementarities (Hall and Soskice 2001; Amable 2003). The varieties of capitalism approach has recently been applied to the regional level as well (e.g. Casper 2007; Crouch et al. 2009), and the sectoral systems of innovation approach frequently overlaps with the regional innovation systems approach.

In sum, there is a rich agenda for exciting scholarly work in theoretical and methodological directions. Progress will profit from more intense interaction between theoretical and applied scholars as well as between economists, geographers and management scientists. We look forward to a lively interdisciplinary debate.

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