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Comparative Industrial Evolution and the Quest for an Evolutionary Theory of Market Dynamics

by

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Comparative Industrial Evolution and the Quest for an Evolutionary Theory of Market Dynamics

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1. Introduction

The suitability of biology as a role model for evolutionary economics has been controversial ever since the times of Veblen and Schumpeter. In the present-day evolutionary community, the debate centers on whether and how concepts from Darwinian evolutionary biology can be fruitfully transferred to the study of economic processes. Positions in this debate range from squarely rejecting the relevance of biological concepts (which essentially replicates Schumpeter's view) to seeing them as the *sine qua non* for any form of evolutionary theorizing. No convergence of positions seems to be on the horizon. Rather, the recent debate on "Universal" or "generalized" Darwinism (kicked off by Hodgson, 2002; see also the contributions to the *Journal of Evolutionary Economics* special issue edited by Witt, 2006) has served to renew the controversy.

Based on an earlier contribution to the debate (Buenstorf, 2006), this chapter suggests that, in understanding the dynamics of markets and industries, biological concepts are only of heuristic use. Moreover, since even biologically inspired heuristics entail framing effects and the discounting of some aspects of the processes under investigation, a pluralism of heuristics rather than the prescription of a specific "evolutionary" heuristic seems warranted in applied research. To develop theories of industry evolution that go beyond a mere collection of empirical findings, the chapter then makes the case for an empirically grounded, "bottom-up" approach to evolutionary industrial economics. This approach to theory building, which might be called "comparative industrial evolution," is based on empirical studies of systematically selected industries that are comparable in key dimensions. It opens up opportunities for testing the relevance, preconditions, and generality of explanatory factors in industry evolution. An illustration of the approach is subsequently given by presenting some findings on the evolution of the historical U.S. farm tractor industry.

The remainder of the chapter is organized as follows: The next section summarizes core controversies in the debate on Darwinian concepts in economics. Section 3 then develops a conceptual framework for comparative empirical work on the evolution of industries and discusses how evolutionary theorizing can be based on the empirical findings. Section 4 presents new results on the evolution of the U.S. farm tractor industry. When juxtaposed to the well-analyzed automobile industry, the tractor industry offers interesting insights into industry evolution. Section 5 concludes.

2. Controversies on Darwinism and Industry Evolution

The heuristic use of biological concepts

When, in 1898, Veblen posed his famous question why economics was no evolutionary science, he referred to the example of Darwinian biology providing a “genetic account of an unfolding process” (Veblen, 1898, p. 388). In his article, Veblen conceives of evolutionary economics as a process theory of cultural and institutional development, which ultimately would have to take human psychology as its point of departure.¹ Beyond this basic commitment to causal explanations of developmental change, Veblen does not invoke any concepts from biology. His basic position is thus not too different from that of Schumpeter (1911, ch. 2) except for the terminology. Schumpeter not only rejected the analogical use of Darwinian concepts in the social sciences, but also the notion of evolution itself, which he considered discredited by dilettantism. Similar to Veblen, however, Schumpeter championed causal explanations of economic development based on qualitative change originating within the industry.

Concepts from Darwinian biology play a larger role in modern evolutionary economics, which took off with the seminal book by Nelson and Winter (1982). Their approach ingeniously combines behavioral organization theory with the metaphorical use of biological concepts. It culminates in the notion of organizational routines being the “genes” of organizations (most notably business firms), which are subject to internal selection as well as external selection by the market process. The routine concept has been extremely influential in both evolutionary economics and management science, and the selection metaphor is a fundamental building block of Nelson and Winter’s modeling approach. However, these authors openly confess to their eclectic “borrowing” (Nelson and Winter, 1982, p. 9) of biological concepts. They dismiss biological accuracy as an objective in itself for evolutionary theorizing in economics, and likewise refrain from attempts at generalizing the Darwinian framework to an abstract, domain-unspecific theory.

In addition to selection, inheritance of organizational routines has also been used as a heuristic to make sense of evolutionary patterns in the development of industries, most notably the origination of capable new entrants (Klepper, 2001; Klepper and Sleeper, 2005). According to this interpretation of the empirical record, founders of intra-industry spin-offs are able to replicate organizational routines by transplanting them from the incumbent firm to

¹ The spirit of this position is remarkably close to the “naturalistic” version of evolutionary economics proposed by Witt (2003) (cf. also Cordes, 2007).

the spin-off. Given that they have previously been tested in the industry, the routines taken over by spin-offs are on average expected to be superior to those accessible to startups whose founders have no background in the industry. Again, this heuristic has proved powerful. For example, it is commonplace terminology to talk about a spin-off's "parent" firm. Likewise, the spin-offs of Fairchild Semiconductors (most notably Intel), which played a decisive role in the evolution of the semiconductor industry in Silicon Valley, have famously been referred to as the "Fairchildren."

The Darwinian metaphor of evolution operating through the selection and inheritance of organizational routines has been adopted in numerous evolutionary contributions. At the same time, prominent evolutionary economists have found it wanting. Foster (1997) argues that it is not doing justice to the historical character of economic evolution, where discontinuous structural change is highly relevant. According to Witt (1999, p. 24), the emphasis on selection "may distract attention from a crucial source of economic evolution: human learning, cognition, and creativity." He furthermore suggests that it may restrict the applicability of evolutionary analysis, thus limiting the potential of the evolutionary approach to economics (Witt, 2003, ch. 1).

From the applied evolutionary economist's perspective, framing the market process in terms of the variation, selection, and inheritance scheme is problematic insofar as it de-emphasizes those dimensions of competition that have no counterpart in the biological realm. Perhaps the most important aspect is a supply-side bias. Markets are loci of *voluntary* exchange where resources cannot simply be appropriated by force. Firms offer goods and services, and their performance depends on finding sufficiently many customers who are willing to pay enough for these goods and services for the firms to recover their costs. Thus, demand factors are crucial for understanding competition and the evolution of industries (Windrum, 2005). There are of course many ways for firms to actively influence the demand for their products, and superior skills in these activities are an important dimension of market competition. These marketing capabilities might be seen as part of a firm's routines, but in evolutionary models that have adopted the routine concept, little consideration seems to be given to them.

More generally, a dynamic view of market competition is not easily squared with the tendency inherent in the selection perspective to see firms as passive objects of selection. In spite of the notion of "interactors" developed as part of a generalized Darwinist framework (Hull, 1988), there is typically little actual interaction between competing and cooperating firms in evolutionary characterizations of market processes. But this interaction is of course at

the core of industrial economics, and numerous ways exist for firms to affect the competitive process and/or preempt its effects. A particularly important dimension of interaction is innovation. To trigger innovative efforts is an important effect of market competition. Successful innovation provides temporary profitability, which subsequently tends to be eroded by the competitive process.

There are likewise limits to the usefulness of the inheritance heuristic. For example, it is by no means obvious on what kinds of knowledge and experiences gained during their tenure at the parent firm spin-off founders actually draw to make their spin-offs successful; and the heuristic fails to offer guidance for finding out. Moreover, the spin-off process involves more than an attempt to copy the parent firm. There is ample evidence suggesting that, while important similarities exist between spin-offs and their parent firms, spin-offs are often based on business models that deliberately depart from the parent firm's strategy. Adverse developments at the parent firm and open disagreements between its management and the future spin-off founder (Klepper and Thompson, 2006) are frequent triggers of spin-off formation.

From Darwinian heuristic to Darwinian ontology?

In recent years, the debate on Darwinian concepts has been refreshed by the proposal to turn the approach of "Universal Darwinism," which was originally developed in evolutionary biology (Dawkins, 1983), into a unifying foundation of evolutionary economics (Hodgson, 2002; Hodgson and Knudsen, 2006). The qualitative change this entails lies in that "Universal" or "generalized" Darwinism is an ontological position. Its proponents argue that, at a sufficient level of abstraction, all evolutionary processes share an identical basic structure, which can be described in terms of the Darwinian principles of variation, inheritance, and selection. "It is not that social evolution is *analogous* to evolution in the natural world [...]. In this sense, social evolution *is* Darwinian." (Hodgson and Knudsen, 2006, p. 14, italics in original).

In some sense, this position is less restrictive than it may seem at first glance. Consistent with the objective of generalization, no claim is made that the Darwinian principles are sufficient to explain the detailed workings of concrete evolutionary processes. Rather, the need for auxiliary, domain-specific explanations is emphasized (Hodgson, 2002). Also, the Lamarckian principle of inheritance of acquired traits is considered admissible as part of the generalized Darwinian scheme. In the most recent exposition, the applicability of the generalized Darwinian scheme is moreover limited to "complex population systems,"

which are defined as systems that “involve a variety of entities that interact with one another” (Hodgson and Knudsen, 2006, p. 3-4).

These qualifications notwithstanding, because of the ontological claim underlying generalized Darwinism, the limitations of the Darwinian heuristic become even more critical. If the basic premises of generalized Darwinism are accepted, then it is but a small step to the position that all evolutionary theorizing must proceed in terms of its variation-selection-inheritance scheme. Framing market processes as selection and inheritance would then no longer be one possible heuristic to be evaluated on the basis of its usefulness, but become the only perspective to be adopted on *a priori* grounds.

Importantly, from an applied perspective, the generalized Darwinian framework is too unspecific to offer much guidance for substantive theory building in evolutionary economics. Accordingly, its proponents have attempted to make it more operational by specifying evolutionary economic processes in more detail. In particular, the Darwinian framework has been applied to the analysis of market competition and industry evolution (cf., e.g., Knudsen, 2002; Hodgson and Knudsen, 2004). At this level of application, firms are construed as interactors (generalized phenotypes), and organizational routines as replicators (generalized genotypes). As has been noted elsewhere (cf. Buenstorf, 2006, for a more detailed discussion), this approach raises some questions.

Organizational routines have attributes that render them less than ideal as units of inheritance or replication. First, routines as “organizational memory” (Nelson and Winter, 1982) are located above the level of the individual employee; and they are at least partially tacit. Both characteristics complicate their replication through individual efforts. Routines may moreover be found at various levels of the organization. Simple routines relate to the firm’s short-term behavior, while more involved, higher-order routines govern activities such as investment and innovation. These differences are not reflected in the generalized Darwinian scheme, as it is based on a homogeneous notion of routine replication.

There is also a variety of potential transmission channels, giving rise to different conditions for the replication of routines. They are argued to be replicated both in-house, e.g., in the setup of new branch plants, as well as across organizations, where replication involves diverse channels such as imitation, consultancies, labor mobility, and spin-off activities. Finally, it is far from clear that routines are the only kind of knowledge that is replicated between firms. The imitation of product designs through reverse engineering is an obvious candidate for an additional replicator at the level of competing firms. However, the assumption of a single, homogeneous replication mechanism at the level of firm interaction

implicitly underlies the application of the generalized Darwinian scheme in industrial economics.² This indicates how the biological template, in spite of the attempt to generalize it and minimize its domain-specificity, still structures the generalized Darwinists' thinking about economic processes.

It may well be that the above issues can be incorporated into future, even more general versions of generalized Darwinism. But that still leaves open the question what would be gained in the process. The abstract framework does not provide information as to how the various transmission channels function (particularly when they are based on individual learning), how important they are in actual competitive processes, and how their relevance varies with changing industrial and environmental characteristics. In the final analysis, then, the payoffs from adopting this research strategy seem severely restricted. As a consequence, a rather different approach to theory building in evolutionary industrial economics will be advocated in the remainder of this chapter.

3. A Comparative Approach to Industry Evolution

The basic philosophy underlying the generalized Darwinian approach may be characterized as a “top-down” strategy. It starts from an abstract framework and endeavors to identify the respective elements of the framework in empirical contexts. In this section, an alternative approach for building theories of economic evolution will be discussed. This approach follows a “bottom-up” strategy, building on the strong empirical tradition in industrial dynamics, in particular the findings suggesting robust patterns in the long-term evolution of industries.

The basic idea is simple. It is to study systematically selected industries that share key characteristics while differing in others. In this way, the role of individual factors shaping the competitive process in different industries can be isolated. However, what seems simple in principle is considerably complicated in practice by the limits to available data. To have a full and comparable account of how industries develop, data are required that cover the complete populations of firms active in these industries over the entire time span of their development. A comparative approach to the study of industry evolution is therefore not easily

² Consistent with some approaches to evolutionary biology, Hodgson (2002, p. 273) stresses the multi-layered nature of economic evolution. He does not discuss, however, the possibility of multiple replication mechanisms at the same level, e.g., competing firms, which has no counterpart in biology.

accomplished. Nonetheless, existing studies have already yielded important results, providing an empirical foundation for theory building.

From its beginnings, the empirical work on industry evolution has been comparative in that developmental patterns have been studied for a variety of industries. The pioneering study by Gort and Klepper (1982) used trade register and patent data to trace the development of active producers and the quantity and kind of innovations in a large set of U.S. industries. A key finding of this study, as well as its subsequent refinement by Klepper and Graddy (1990), was to identify regularities of industry evolution (which subsequently became known as the “industry life cycle,” cf. Klepper, 1997). In particular, entry peaks early in most industries, and the industries then undergo a “shakeout” phase during which the number of active producers is rapidly reduced. Also, the importance of product innovations, relative to process innovations, tends to decline as industries mature. Based on a study of four shakeout industries, Klepper (2002a) furthermore concludes that early entrants had a significantly higher likelihood of survival than later ones.

These regularities of industry evolution fall short of being universal laws, however. Not all industries developed in the same way. For example, in 19 out of the 46 industries studied by Klepper and Graddy (1990) no shakeout in the number of firms was observed. It is therefore a crucial task for research in industrial evolution to identify alternative developmental patterns as well as their drivers. One alternative pattern that has found much scholarly attention is observed in industries such as the laser industry, where products are heterogeneous and most producers specialize on a small number of submarkets (defined by product type). The U.S. laser industry has been characterized by positive net entry and increasing numbers of producers over several decades. Also, early entrants did not survive longer than later ones in this industry (Sleeper, 1998; Klepper and Thompson, 2005).

Empirical regularities such as the shakeout phenomenon and advantages of early entry indicate that the competitive process undergoes significant changes as an industry matures. The Darwinian scheme of variation, selection, and inheritance of routines is of little use in trying to account for these changes. Why does the number of producers change, and why exactly is early entry beneficial? Answers to such questions are provided by theoretical models of industry evolution, e.g., by focusing on the larger size of earlier entrants, giving them more incentives to do process R&D, which in turn enhances future performance and raises the barriers to new entrants (Klepper, 1996). Thus, an explanation is sought in terms of internal change in incumbent firms rather than changes at the population level focused upon by the Darwinian model. Indeed, declining entry rates in maturing industries suggest that

population changes become less important over time for industry evolution. Likewise, the differences between alternative patterns of industry evolution are more amenable to an explanation in terms of product market characteristics (ultimately reflecting differences in demand patterns) than in terms of routines and their selection. For example, the specialization along submarkets found in the laser industry can be explained by pronounced product heterogeneity with low degrees of substitutability on the demand side, combined with lacking economies of scope on the supply side.

Numerous empirical studies have also found that the odds of success vary between entrants with different pre-entry backgrounds (Helfat and Lieberman, 2002). A pervasive finding is that diversifying producers from related industries on average outperform entrepreneurial *de novo* entrants (Klepper, 2002a). Substantial differences in performance are also observed within the latter group, with much effort being devoted to studies of intra-industry spin-offs, i.e., firms started by former employees of incumbent firms in the industry. As a group, spin-offs are generally superior to other *de novo* entrants. In several industries they performed as well as diversifying entrants (Dunne et al., 1988; Sleeper, 1998; Agarwal et al., 2004). Spin-offs are more likely to originate in more successful firms (Buenstorf and Klepper, 2005), and the performance of parent and spin-off firm is positively related (Klepper, 2002b). Moreover, both the time of tenure and the position of spin-off founders at the parent firm predict spin-off performance (Dahl and Reichstein, 2006). At the same time, the importance of the alternative types of experienced entrants strongly varies across industries. For example, while the U.S. automobile industry was dominated by spin-offs, spin-offs were inconsequential among producers of television receivers, and all major TV producers had originally been started as radio manufacturers (Klepper and Simons, 2000; Klepper, 2002b).

Many of these findings are consistent with the interpretation that inherited organizational routines are transferred to new markets (in the case of diversifiers) or new firms (spin-offs). This leaves open a number of crucial questions, however. Is it specific capabilities or general experience gained in previous activities that matter most for the performance in the new industry? Are there differences in the relevance of capabilities related to different activities, e.g., R&D, production, and marketing? How exactly are these capabilities transferred? What industry characteristics determine their effect on performance? And why are spin-offs and diversifiers not equally prevalent in all industries?

Comparing industries with different product characteristics helps to answer some of the questions regarding differences in evolutionary patterns and the effects of pre-entry

experience. Further insight can be gained by comparative work along other dimensions, in particular by international comparisons. All initial studies of industry evolution were based on U.S. data. In recent years, however, researchers have begun to analyze the same industry in different countries, or at least study whether patterns found in the U.S. also characterize analogous industries in other countries. This kind of comparison is particularly important because it allows for a direct test of the assumption that technological factors (rather than, e.g., institutional ones) are the critical determinants of the observed regularities, which implicitly underlies the theoretical work on industry evolution.

Simons (2001) compares trends in the number of producers in the U.S. and the U.K. for 18 of the industries featured in Gort and Klepper (1982). He finds remarkable similarities between both countries in both the timing and the severity of shakeouts in the various industries. A detailed analysis of two shakeout industries, tires and TV receivers, indicates that early-mover advantages were present in both countries. Cantner et al. (2006) study the German automobile industry. They find that the evolutionary patterns in this industry, most notably the effects of early entry and pre-entry experience on firm survival, mirrored those of the U.S. automobile industry. In a similar vein, Boschma and Wenting (2005) compare the geographic structure of the British and the U.S. automobile industries. Buenstorf (2005) studies lasers, a prominent non-shakeout industry, using data on German laser producers. Again consistent with the U.S. patterns for the analogous industry, he finds an increasing number of producers over a 40-year period of industry evolution, no advantages of early entry, and no positive effects of pre-entry experience on firm performance. A complementary strategy exploits idiosyncratic historical events affecting the evolution of a national industry. For example, Buenstorf and Guenther (2006) study the effect of regional industry agglomerations on the location choice of German machine tool producers. To control for effects of regional “birth potential” (Carlton, 1979; cf. also Buenstorf and Klepper, 2006), they specifically concentrate on those firms that moved from East Germany to West German locations after World War II.

Finally, comparative work to identify key determinants of industry evolution can also be based on data for industries that manufacture closely related products and operate under similar institutional conditions. An example of this approach is provided in the next section, where some findings on the evolution of the U.S. farm tractor industry are presented. This industry was selected because in its formative years its product was very similar to that of the automobile industry, which is one of the best studied industries in the literature on industry evolution. Indeed, in extreme cases, the boundary between the two products became blurred.

For example, several producers in the 1910s marketed conversion kits allowing customers to use their automobiles as makeshift tractors. (In the long run, these conversion kits were unsuccessful because critical components such as radiators and bearings were overburdened in prolonged operation at low speeds.)

4. Automobiles and Farm Tractors: Lessons from Comparing Two (Seemingly) Similar Historical Industries

To study the evolution of the U.S. farm tractor industry, a new dataset was constructed with the objective to maximize comparability to the prior work on the U.S. automobile industry. The most important primary source of information on tractor producers is *Thomas' Register*, which was already used in Gort and Klepper's (1982) discovery of the shakeout phenomenon, and likewise in many later studies of industry evolution. However, in the case of tractors this source has two major shortcomings. First, in the industry's early years listings of tractors are lumped into the listings of (traction) engines, and the distinction between steam-powered traction engines (which are not included in the present analysis) and tractors with an internal combustion engine is not clear. Second, *Thomas' Register* does not list farm tractors separately from road tractors. Accordingly, among the more than 1,200 tractor firms listed many did not actually make farm tractors. To account for this, the dataset is restricted to firms that are listed as tractor producers both in *Thomas' Register* and in the *Encyclopedia of American Farm Tractors* (Wendel, 1979) and/or the *Standard Catalog of Farm Tractors, 1890-1960* (Wendel, 2000). The same sources were used to identify the backgrounds of firms.

In total, there were 319 confirmed entrants into the tractor industry until 1940. This number includes 56 prior engine producers (including producers of steam-driven traction engines), 40 prior producers of agricultural implements, 21 diversifying automobile and truck producers, and 22 preexisting firms with other backgrounds, including, e.g., general manufacturing firms, makers of construction equipment, as well as a foundry. Some firms had experience in several of these industries, which is reflected in the coding of backgrounds. In addition, 13 spin-offs founded by employees leaving incumbent tractor firms could be identified.

The information on firm backgrounds already indicates the presence of substantial differences between the tractor and automobile industries. First, in tractors the share of spin-offs from incumbent firms in the industry was substantially smaller than it was in autos.

Second, diversifiers came from a different set of industries, with prior implement producers being the second-largest group after engine producers. In contrast, makers of carriages and wagons, and bicycle producers, were (along with engine makers) the most prominent groups of diversifiers in the automobile industry (Klepper, 2002b). This prominence of implement makers suggests that relatedness in terms of markets and customers may have been more important for the decision to diversify than technological relatedness. For example, it is not obvious what kind of technological capabilities should qualify a plow manufacturer such as John Deere to become a successful tractor maker.

To study the role of background as a determinant of performance, longevity is adopted as a performance measure, and an econometric survival analysis is conducted. Again, this approach follows the earlier work on the automobile industry, as well as the bulk of empirical studies on industry evolution. Using survival in the market as a performance criterion is in part dictated by the (non)availability of financial data on all but the largest firms in the population. There are, however, numerous reasons why longevity is a suitable proxy for performance. The underlying assumption is basically an opportunity cost argument. If firms leave this market, they do so either because they are forced to (i.e., they are bankrupt) or because the firms' owners think there are better uses for their capital. Given irreversibility of at least some earlier investments, one can (at least for manufacturing industries like the one considered here) be quite certain that the decision to voluntarily leave the market indicates a substandard performance of the respective firms.³

Generally speaking, survival analysis models the risk ("hazard") of succumbing to some event conditional on vectors of explanatory variables. A variety of specifications are available for survival models. Below, the fully parametric Gompertz specification is adopted. This model setup has two characteristics that are helpful in the present context. First, in contrast to other specifications, notably the popular semi-parametric Cox regression, the proportionality of hazards among different groups of entrants need not be assumed. Second, the influence of firm age (time after entry) on the exit hazard is explicitly modeled.

– Insert Table 1 around here –

³ Some firms disappear from the dataset because they are acquired by other tractor firms. In these cases, exit does not provide systematic information on prior performance. Accordingly, the fact of being acquired is not taken into account in the survival analysis, but only the information that the firm survived up to the time of its acquisition (i.e., acquisitions are treated as censored exits).

Results of the survival analysis are reported in Table 1. Model 1 is the proportional benchmark model in which the age-dependent part of the exit hazard is not separately estimated for the various types of entrants. The model includes dummy variables denoting the various types of diversifiers (prior makers of implements, engines, autos and trucks, and other diversifiers) as well as spin-offs; other de novo entrants are the non-reported control group (they are referred to as startups below). The model also includes a set of dummies that sort entrants into age cohorts, where each cohort corresponds to a decade of entry. Estimation results suggest that among the diversifiers, only firms with a background in agricultural implements and prior engine producers performed systematically better than the startups. In contrast, the diversifying auto and truck producers and the residual group of diversifiers with diverse backgrounds have lower exit hazards than the startups, but these effects are smaller and statistically insignificant. The same holds for the group of spin-offs, even though their coefficient estimate suggests that their performance was comparable to that of the diversifying engine producers. The cohort dummies indicate that once the background of entrants is accounted for, there were at best weak advantages of early entry in the tractor industry. The oldest cohort has a slightly lower hazard than the control (cohort 4), whereas both intermediate cohorts have substantially larger hazards. Only the coefficient estimate for cohort 2 is marginally significant (at the .10 level), however.

In Model 2 (Table 1) the hazard of the entry cohorts is allowed to vary over time. For each cohort, there are now two coefficient estimates. The estimates reported in the upper part of Table 1 denote the hazard that firms of the respective type had at age 1, whereas the second set of estimates denote the age-dependent hazards. Including these terms wipes out the significance of the performance effect of prior engine production, while the effect of prior production of agricultural implements is robust to this modification. Both sets of coefficient estimates for the cohort variables are statistically indistinguishable from zero, but the log-likelihood of the model increases significantly relative to Model 1, suggesting that the age-dependent hazard terms are jointly significant and the proportionality assumption underlying Model 1 cannot be upheld.⁴

Model 3 adds another set of age-dependent hazard terms for the alternative kinds of pre-entry experience. In comparison to the earlier models, there is one substantial change in the results: the aggregate group of diversifiers with diverse backgrounds has a significantly lower initial hazard than the control group. In fact, their early performance almost matches

⁴ This finding also rules out the use of alternative survival techniques such as the Cox regression.

that of the best performing group, the prior implement makers. At the same time, they are the only group whose exit hazard significantly increases with firm age. In contrast, the initial performance of diversifiers from the automobile industry as well as spin-offs is even less distinctive than suggested by the earlier models, indicating that these entrants benefited little from the capabilities they brought to the tractor industry. Finally, another piece of information on tractor producers is included in Model 4. It is well known that many early tractor firms did not produce their own engines but purchased engines as components from other producers. For a number of firms, the *Standard Catalog* (Wendel, 2000) reports whether they installed own or purchased engines in their earliest tractor model. This information can be interpreted as a proxy for the technological capabilities that an entrant possessed. Surprisingly, Model 4 finds that, if anything, those entrants of which we know they entered using own engines performed below average, whereas entrants using purchased engines may have fared better than average. Both coefficient estimates are not significantly different from zero, however.

How can we explain the substantial performance differences among tractor producers as indicated by the survival analysis? Perhaps the most striking result is that in the tractor industry, prior producers of agricultural implements benefited more from their pre-entry experience than either engine producers or automobile firms did. This is puzzling since, first, the engine is the most complex component of a tractor and, second, tractors and automobiles (and trucks) were closely related technologically in the early 20th century, which would suggest some kind of scope economies between both markets. Apparently, performance differentials were not primarily driven by technological capabilities. This interpretation is consistent with the finding that tractor firms constructing their own engines (which presumably were among the more technologically versed entrants) did not outperform other producers.⁵

Automobile producers were not only in the technological vanguard of manufacturing in the early 20th century, adhering to stricter engineering standards than most other firms, including implement makers. Production volumes for autos also picked up speed much quicker than those for tractors, turning automobile firms into large-scale organizations accustomed to standardization and mass manufacturing (Williams, 1987). Presumably therefore, automobile producers possessed both technological capabilities and more general organizational routines allowing them to dominate the tractor industry. Indeed, major U.S. automobile producers, most notably Ford but also others such as General Motors, Maxwell,

⁵ The development over time in the hazards of diversifiers with various backgrounds suggests that many of them entered the tractor industry opportunistically, expecting quick profits, and not without initial success.

and Chandler, tried to gain control of the tractor market. Ford was the most aggressive. Similar to their prior strategy in the auto industry, they introduced a low-cost, mass-produced tractor in 1917. Ford's entry boosted production volumes and helped to raise engineering standards in the tractor industry. The firm also started a price war by drastically cutting its prices, but eventually lost out to International Harvester and temporarily withdrew from production in the U.S. in 1928 (*ibid.*).

In addition to severe design flaws of the "Fordson" tractor, Ford's defeat has been attributed to the firm's failure to set up a distinct distribution network for tractors and to sell tractors as part of a larger system of farm equipment.⁶ In contrast, agricultural implement producers had extensive networks of marketing outlets in the rural U.S.. Their decisive competitive advantage thus appears to have been their superior access to customers, which made them better informed about customer needs, enabled them to introduce commercially successful product innovations, and may also have made them more credible in the eyes of their customers. Based on their familiarity with the farm equipment market, implement makers like International Harvester were able to introduce design innovations such as the general-purpose tractor, which was attractive to the average U.S. farmer, including growers of row crops, and decisively widened the tractor market (Williams, 1987, chs. 4 and 5).

The second major difference between the tractor and the automobile industries is that, while spin-offs played a crucial role in the evolution of the automobile industry, they were relatively rare and their performance was unspectacular in the tractor industry. This may have had to do with the strong showing of implement makers leaving little room for innovative spin-offs. Klepper (2005) conjectures that the degree of technological novelty in a new industry conditions the success of diversifiers from related industries, and the extent to which opportunities open up for innovative spin-offs. The present analysis indicates that diversifiers' ability to transfer capabilities depends on the relatedness of markets in terms of demand factors as well as technological proximity. This is in line with Klepper's basic conjecture, however: the spin-off process may only be prominent in industries where diversifiers leave it enough room.

The finding regarding spin-offs is moreover interesting with regard to the evolution of the tractor industry's geographic structure. Whereas the automobile industry became heavily concentrated in and around Detroit, the tractor industry was characterized by much less

⁶ When Ford was able to make a comeback in 1939, this was due to the duplex hitch invented by Harry Ferguson, a self-taught British mechanic (Williams, 1987, ch. 6). Ford is treated as a continuing producer in the survival analysis.

geographic concentration. These patterns are entirely consistent with the spin-off-based account of industrial clustering proposed earlier (Klepper, 2004, 2005; Buenstorf and Klepper, 2005): In the automobile industry, the Detroit cluster mainly emerged due to high-performance spin-offs that originated in the region and located close to their geographic roots. In contrast, the diversifiers that became dominant in the tractor industry were much more widely spread out (mostly all over the Midwest), while the spin-off process was too weak to drive a process of regional agglomeration.

5. Concluding Remarks

This chapter discussed alternative approaches to evolutionary research on industrial dynamics. It juxtaposed two basic research strategies. One strategy is based on the adoption of the abstract framework of Darwinian evolutionary biology, which is used as a template for economic analysis. In its heuristic form, this strategy has been popular in evolutionary economics for the past 25 years, going back to Nelson and Winter (1982). It has evidently been very successful, despite some potential pitfalls of the heuristic that have been pointed out above. More recently, a “generalized” Darwinist framework has been advocated as the shared ontological foundation of processes in, among other fields, biology and economics. As has been argued in this chapter, the ensuing endeavor to use generalized Darwinism as the foundation of an operational framework for studying industrial dynamics – interpreted as being driven by the selection and inheritance of organizational routines – has left many unsolved issues to date.

Comparative empirical work has been suggested as an alternative research strategy. There is a wealth of empirical studies on industry evolution, and, implicitly, this strand of literature has been comparative in nature from the beginning. In addition to the study of different industries in the same country, studies of the same industry in different countries have recently been taken up. Moreover, models of industry evolution have been developed that are evolutionary in character, but have at most cursory and heuristic recourse to the Darwinian framework.

The chapter’s principal conceptual objective was to make more explicit the comparative character of the empirical work, and to propose the strategic selection of industries as a deliberate “bottom-up” research strategy enabling the development of theories of industry evolution. In addition to cross-national comparative work, studies of industries

that are or have been subject to nation- or industry-specific exogenous shocks, as well as an analysis of closely related industries have been advocated as research designs allowing to gain new insights into the processes and determinants of evolutionary dynamics in industries. With this emphasis on the comparability of industry studies, the chapter was also intended to help shape an agenda for empirical research in industry evolution that is conducive to theory building. This resonates with the recent proposal to focus empirical attention on irregularities rather than regularities of industry evolution (Klepper and Thompson, 2005).

The chapter concluded by illustrating this approach with an empirical example. Results for the historical U.S. farm tractor industry were presented and discussed against the backdrop of findings on the automobile industry, which was very similar in terms of product technology and has been thoroughly studied before. The example indicated substantial differences between the two industries in the prevalence and performance effects of pre-entry experience. Most importantly, diversifiers from agricultural implement making dominated the tractor industry, and there were few spin-offs, which mostly had little impact on the industry's further development.

The patterns in the tractor industry suggest that knowledge about customer needs and marketing capabilities are important success factors in innovative industries. This conclusion from studying the tractor industry is consistent with earlier findings in a study of German laser producers (Buenstorf, 2005). While spin-offs were numerous and on average quite successful in lasers, another group of entrants performed just as well: prior laser distributors that integrated into laser manufacturing. These firms could neither bring in detailed knowledge about organizational routines from successful laser producers, as their founders had not been insiders to these firms before, nor were they distinctive in their technological capabilities. (University spin-offs, on the other hand, that presumably did have superior technological capabilities, tended to be among the least impressive performers in the laser industry.) Furthermore, the small number and unimpressive performance of spin-offs in the tractor industry coincided with the absence of a pronounced geographic concentration. This lends support to the theories of spin-off-induced clustering that have been derived from earlier industry studies. Apparently, spin-offs are not only conducive to the emergence and evolution of geographic concentrations, but a lack of spin-offs may also prevent clusters from forming.

Findings like these indicate the potential of the comparative approach to lead to new, detailed insights into the kinds of individual knowledge and organizational capabilities that can be transferred between firms and industries, shaping the competitiveness of new entrants and the way that industries develop. The concrete findings, albeit still preliminary and sketchy

in nature, are much more specific than the notion of inherited routines derived from the framework of generalized Darwinism, and they are open to subsequent testing and refinement.

There are, of course, limitations also to the “bottom-up,” comparative research strategy proposed here. Some are inherent in that as an essentially inductive approach, it requires complementary sources of research questions and hypotheses to be tested. This is where heuristics from biology may play a role, then being a complement to the detailed empirical work. However, there is no obvious reason why biological concepts should necessarily play a special role in this context. Other sources of inspiration may be as fruitful, for example concepts borrowed from disciplines other than biology, historical and contemporary case study evidence, and more applied theoretical models. Other limitations to the approach derive from data availability. To date, no industry study has had access to full information on the complete firm population, including dimensions such as output and profitability statistics, product prices, detailed information on customers and market segments, etc. However, more and more empirical work on industry evolution is being done, and new datasets are increasingly becoming available to the applied researcher. Thus, the frontier of knowledge about industry evolution is gradually shifting.

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**Table 1: Survival and Firm Characteristics in the U.S. Farm Tractor Industry
(Entrants through 1940; hazard models in Gompertz specification)**

	Model 1	Model 2	Model 3	Model 4
Agric. Impl. Diversifiers	-.967*** (.229)	-.996*** (.232)	-.995*** (.314)	-1.021*** (.315)
Engine Diversifiers	-.417** (.206)	-.333 (.207)	-.345 (.274)	-.395 (.274)
Auto/ Truck Diversifiers	-.230 (.239)	-.139 (.240)	-.069 (.295)	-.124 (.298)
Other Diversifiers	-.055 (.227)	-.079 (.227)	-.761** (.364)	-.814** (.367)
Spin-offs	-.391 (.328)	-.402 (.220)	-.253 (.423)	-.299 (.432)
Own Engine				.176 (.223)
Purchased Engine				-.172 (.147)
Cohort 1	-.040 (.436)	-.466 (.642)	-.453 (.655)	-.457 (.654)
Cohort 2	.675* (.390)	.792 (.583)	.809 (.583)	.848 (.584)
Cohort 3	.627 (.405)	.860 (.601)	.883 (.602)	.919 (.604)
Constant	-2.393*** (.389)	-2.457*** (.577)	-2.463*** (.576)	-2.443*** (.581)
Agric. Impl. Diversifiers * t			.001 (.015)	.001 (.015)
Engine Diversifiers * t			.003 (.014)	.004 (.014)
Auto/ Truck Diversifiers * t			-.008 (.024)	-.009 (.024)
Other Diversifiers * t			.131*** (.044)	.129*** (.044)
Spin-offs * t			-.027 (.056)	-.024 (.057)
Cohort 1 * t		.026 (.033)	.024 (.034)	.023 (.034)
Cohort 2 * t		-.014 (.033)	-.018 (.033)	-.017 (.033)
Cohort 3 * t		-.031 (.037)	-.030 (.037)	-.028 (.037)
t	-.023*** (.006)	-.019 (.031)	-.019 (.031)	-.019 (.031)
No. firms (uncens. exits)	319 (271)	319 (271)	319 (271)	319 (271)
Log-likelihood	-444.403	-438.906	-434.813	-433.607
P > chi ²	.000	.000	.000	.000

Standard errors in parentheses; ***P≤.01; **P≤.05; *P≤.10