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Evolution of Vertically Related Industry Populations: The Case of the German Piano Industry

Roland Stuerz
Max Planck Institute for Innovation and Competition
Munich Center for Innovation and Entrepreneurship Research
roland.stuerz@ip.mpg.de

Abstract

Research on the evolution of industries so far had devoted little attention to the vertical structure of companies along an industry?s value chain and the change of this structure over time. This study builds on previous research about industrial life cycles and theoretical concepts dealing with the vertical boundaries of firms and develops a model of the evolution of vertically related populations in an industry. It is argued that disintegration incentives within an industry increase over time basically due to a reduction of uncertainty but that the necessary conditions for vertical disintegration to take place will only be met around the emergence of a dominant design. A case study of the evolution of the German piano industry including detailed quantitative demographic data on all known firms is in line with the model?s predictions. Piano manufacturers were integrated firms in early phases of the industry and a considerable emergence of suppliers only set in with the occurrence of the dominant design. The study contributes to the existing literature by developing a holistic theoretical model of the evolution of industries allowing for important conclusions on the relation between technological development and vertical differentiation with profound strategic implications.

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1. Introduction

In the past decades, research on the evolution of industries and organizational populations has led to diverse theoretical models and perceptions about the co-evolution of categories, technologies and innovations, the orientation of research and development as well as legitimation and competition with industrial dynamics and the demographic composition of organizational populations (Carroll & Hannan, 2000; Klepper, 1997; Nelson, 1994; Núñez Nickel & Moyano Fuentes, 2004; Suarez, Grodal, & Gotsopoulos, 2014; Utterback & Abernathy, 1975). However, in all these models little attention has been devoted to the vertical structure of companies along an industry's value chain and the change of this structure over time (Jacobides, 2005; Klepper, 1997). In 1951, Stigler already outlined the tendency towards vertical specialization within an industry (Stigler, 1951). Additionally, a series of case studies found a specialization in industries over time (Cacciatori & Jacobides, 2005; Christensen, Verlinden, & Westerman, 2002; Jacobides, 2005; Macher & Mowery, 2004). However, researchers started only recently to examine the phenomenon of vertical disintegration in the context of industry evolution more closely. On the one hand, theoretical and empirical contributions on the prerequisites necessary for vertical disintegration were developed (Christensen et al., 2002; Jacobides, 2005). On the other hand, formal simulation models that either abstractly model the advancement of vertical structures of companies in an industry over time (Arora & Bokhari, 2007; Jacobides, 2008) or trace the historical development of a specific industry based on theoretical considerations (Malerba, Nelson, Orsenigo, & Winter, 2008) have been presented.

An important starting point of such research efforts is the recognition that the classical transaction cost theory (Williamson, 1975, 1985) as a mainly static concept for the evaluation of make-or-buy decisions may only partly contribute to answer questions about the development of vertical firm structures in an evolutionary context (Jacobides, 2005). This is due to the fact that this approach considers technologies, product features and intermediary markets as given and examines integration or disintegration decisions only at specific points in time (Malerba et al., 2008). However, markets for an exchange of upstream products may often not exist initially in an industry and may only develop over time (Cacciatori & Jacobides, 2005; Jacobides, 2005).

The resource-based approach (Barney, 1991) presents a second theoretical basis for an analysis of vertical organizational boundaries (Macher, 2006; Nickerson & Zenger, 2004; Wolter & Veloso, 2008) and complements the transaction cost approach (Cacciatori & Jacobides, 2005). However, most studies that do not only take into account a firm's transaction costs but also its competencies and resources for an analysis of the vertical expansion of companies also fall short, because they do not adequately incorporate the technological development that is associated with the typical industry life cycle (Wolter & Veloso, 2008).

Hence, a more integrated theoretical reasoning combining knowledge about the industry life cycle and the development of transaction costs and business competencies within individual firms and the whole industry over time is needed to better understand the evolution of an industry (Jacobides & Winter, 2005). A better understanding of evolutionary dynamics and changes of vertical structures within an industry over time is important for several reasons. Different competitive situations within an industry that emerge with changes of the structure along an industry's value chain may call for different competencies and capabilities of industry participants. Thus, the structural change over time has profound strategic implications for firms and a detailed understanding of this change may help executives to anticipate future developments (Jacobides, 2005). A better understanding of evolutionary dynamics can also contribute to a general broadening of perspectives and help public authorities to better forecast long-term developments by enlarging their limited prevision (Jacobides & Winter, 2005).

Building on previous research a model of the evolution of vertically related populations in an industry is developed. I argue that disintegration tendencies within an industry increase over time basically due to a reduction of uncertainty. However, the necessary conditions for vertical disintegration to take place, namely coordination simplification and information standardization (Jacobides, 2005), will only be met around the emergence of a dominant design (Suarez & Utterback, 1995; Utterback & Abernathy, 1975). Thus, the convergence to a dominant design will enable the formation of new organizational populations of suppliers and of new markets along the value chain of an industry.

The theoretical model derived is examined with a case study of the evolution of the German piano industry including detailed quantitative demographic data on all known German piano manufacturers and its German supplier firms. In accordance with the theoretical prediction, piano manufacturers were integrated firms in early phases of the industry and a considerable emergence of suppliers only set in with the occurrence of the dominant design.

The study contributes to the existing literature by developing a holistic theoretical model of the dynamic development of vertically related populations along an industry's value chain by linking sociological, managerial and economic research on industry evolution. The investigation extends existing research and complements case studies of other industries by going beyond the usual anecdotal evidence (Cacciatori & Jacobides, 2005; Christensen et al., 2002; Jacobides, 2005; Macher & Mowery, 2004) by presenting the demographic change of the vertically related populations. This allows for important conclusions on the relation between industry evolution and vertical differentiation.

The paper is structured as follows. First, I will outline the theoretical background and develop a model of the evolution of vertically related populations within an industry. Second, the evolution of the piano instrument and the German piano industry is presented to allow me to link this evolution to the developed theoretical model in the next step. The paper concludes with a summary, a discussion of implications and limitations and further avenues of research.

2. Industry Life Cycle and Vertical Industry Structures

Models of industry evolution

Mueller and Tilton (1969) were among the first to describe an industrial life cycle. Their considerations were grounded on the two different technological regimes expressed by Schumpeter (Winter, 1984). Whereas in Schumpeter's (1912) early works small, new and entrepreneurial firms were seen as drivers of technological change, in later years Schumpeter (1942) expressed the view that the technological progress is driven primarily by large and established companies. Mueller and Tilton (1969) specified a dynamic change of one regime to the other with an industry's age and described four different phases of industry evolution.

The initial phase, when a new process or a new product is invented, is characterized by high uncertainty concerning both technology and market potential. With the successful introduction of the invention in the second phase an essential part of this uncertainty is eliminated as other firms can now evaluate the innovation and its commercial potential. In most cases the original innovator will be unable to monopolize the innovation and other firms will enter the market using own R&D to create own variants of the innovation. Often knowledge about the technology is still restricted and R&D is intended to increase knowledge. Research activities in many cases cannot be split and spread across different teams and rely heavily on simple and makeshift experiments. Economies of scale and entry barriers are likely to be low in this early phase, so that firm size does not constitute a competitive advantage. Hence, small firms may numerously enter the industry and advance the development of the technology (Mueller & Tilton, 1969).

In the third phase, R&D is becoming increasingly complex and a specialized function. Now the technology can be split into different components and improvements are directed at these components. Incumbents built up entry barriers for new firms by establishing intellectual property rights and companies with large R&D departments now enjoy a competitive advantage over their smaller competitors. Industry entries decrease and once incumbent firms meet market demand, competitive pressure among existing organizations forces weaker firms to exit the industry. In the fourth phase, production processes are largely standardized and technological advancement slows down. The initial technological competition has shifted to price competition. Consequently, the model describes a transition from an entrepreneurial regime where small firms are the drivers of technological progress to a routinized regime where large firms are dominating (Mueller & Tilton, 1969; Winter, 1984).

Based on these considerations, the so-called Abernathy-Utterback-Model assumes a quite similar evolution of industries. However, it complements the initial concept with the central assumption of a convergence to a dominant design (Abernathy & Utterback, 1988; Utterback & Abernathy, 1975; Utterback & Suarez, 1993). “A dominant design usually takes the form of a new product (or set of features) synthesized from individual technological innovations introduced independently in prior product variants” (Utterback & Suarez, 1993, p. 1).

According to this model, the evolution of an industry starts with a fluid phase when small, young and flexible companies make a radical innovation. Uncertainty about customer needs and performance requirements are high (Abernathy & Utterback, 1988). Moreover, the functionality of the products is often not sufficient to satisfy the mainstream market (Christensen et al., 2002). Consequently, companies compete with different, often customized product designs addressing different needs and numerous major product innovations occur. Inputs are restricted to generally available materials (Abernathy & Utterback, 1988).

In a second transitional phase, at least one stable product design variant allows for a high volume of production and production processes become more rigid. Process innovations driving down production costs become more and more important and start to dominate over product innovations. Now some specialized inputs may be demanded provided that suppliers exist. The industry converges to the dominant design and in the third specific phase largely undifferentiated products based on this design are produced at low cost and high volume. Minor incremental product and process innovations stepwise enhance product quality and production efficiency. The production processes are now rigid and capital-intensive and manufacturers demand numerous specialized inputs (Abernathy & Utterback, 1988).

Mueller and Tilton (1969) as well as Abernathy and Utterback (1988) describe an industry life cycle that is consistent with the empirical observation of the evolution of many industries with numerous entries of companies in the beginning, followed then first by a decrease in entries and later by a ‘shakeout’ with many market exits. In a final phase, market entries and exits hardly occur, resulting in a stabilization of firm numbers (Gort & Klepper, 1982; Klepper, 1997).

Even though both concepts describe a specialization of various functions over time and a demand for specialized inputs in later evolutionary phases, they basically remain silent about the emergence, rise and fall of specialized suppliers (Jacobides, 2005; Klepper, 1997).

Utterback and Suárez (1993) note with regard to the Abernathy-Utterback-Model that in early versions of the model vertical integration of activities in the final developmental phase was considered to be a necessary result of the evolutionary process. In newer formulations, however, this prediction is relaxed and the control over the value chain either by vertical integration or by other mechanisms is considered as an important outcome. However, empirical findings on vertical disintegration rather than integration of industries over time (Christensen et al., 2002; Jacobides, 2005; Macher & Mowery, 2004) cannot be explained by these theoretical considerations.

The same holds true for Klepper's (1997, 2002) economic industry life cycle model. The model primarily differs from the Abernathy-Utterback-Model as it does neither predict nor require the convergence to a dominant design. It rather assumes that firms are heterogeneous in terms of their abilities and try to reduce their average unit costs by conducting R&D leading to process innovations. Larger firms in this case shall reach a considerable competitive advantage over smaller firms, as the lower unit costs are scaled by output volume. At the outset of an industry's evolution, costs impeding an infinite and rapid growth of firms still enable numerous new firms to enter the market. However, with the gradual growth of incumbents R&D efforts lead to price reductions, making an entry for new firms unprofitable at some point. Eventually, also smaller, less capable incumbent firms are forced to leave the market resulting in a 'shakeout'. Finally, the reduced number of competing firms also offers a reduced number of different product variations (Klepper, 1996, 1997, 2002).

A further model explaining the observable evolution of industries stems from organizational ecology (Hannan & Freeman, 1977). Following the logic of bio-ecology, a logistic growth function is assumed:

$$\frac{dN}{dt} = rN\left(\frac{K\text{-}N}{K}\right) \tag{1},$$

where the change of a population with size N is defined by a natural growth rate r and the limit K representing the carrying capacity of the environmental resource space (Hannan & Freeman, 1977; Lambkin & Day, 1989).

Depending on the population's level of development and proximity to the carrying capacity, two fundamental organizational strategies are distinguished. At the outset of the development, so-called '*r*-strategies' are of advantage. Firms following an '*r*-strategy' can easily be set up as they exhibit simple structures and low capital intensity. They exploit resources quickly as they become available and their success depends primarily on a ‘first-mover-advantage’. Firms following an ‘*r*-strategy’ predominantly exist in environments characterized by high uncertainty about the availability of resources and by a broad distribution of these resources (Brittain & Freeman, 1980). Accordingly, ‘*r*-strategists’ are likely to enter an industry at an early stage, where explorative strategies are of advantage (Brittain & Freeman, 1980; Lambkin & Day, 1989). As soon as the population size reaches the carrying capacity, so-called ‘*K*-strategies’ are more suitable. Firms following a ‘*K*-strategy’ are mainly competing on their efficiency. They are characterized by clear structures and high capital intensity but are less flexible and more slowly in opening up new dimensions of the resource space than ‘*r*-strategists’ (Brittain & Freeman, 1980). ‘*K*-strategists’ mainly occur in later evolutionary phases particularly when innovations are of incremental nature and firms focus on process innovations (Hunt & Aldrich, 1998).

The model resembles the understanding and assumptions of the other industry life cycle concepts but does also make no predictions about the development of vertical structures in an industry.

Within this model, two precisely defined sociological forces namely ‘social legitimation’ and ‘diffuse competition’ play an important role (Carroll, 1997; Carroll & Hannan, 1989b, 2000). At the beginning of the evolutionary cycle, the very first organizations of their kind lack this form of legitimation. Further market entries strengthen social legitimation resulting in an increase of firm numbers. However, once full legitimation of the industry is reached, competitive effects of incumbents on each other dominate and weaker organizations are forced to exit the market (Carroll & Hannan, 1989b, 2000). A pronounced ‘shakeout’ may occur because of a high number of exits of less capable firms that were established in times of high competitive pressure with a lot of incumbents being present. Firms that entered during those adverse environmental conditions are believed to be bound to inferior regions of the resource space and thus to be disadvantaged compared to competitors that entered during times with less competition (Carroll & Hannan, 1989a).

The model differs markedly from the other concepts with regard to the forces believed to drive industry evolution since technological change and a shift of technological regimes play no fundamental role. However, the approaches are not contradictory but instead complement each other. In order to be able to make predictions about the development of vertically related populations within an industry, the presented models need to be extended using other theoretical concepts that deal with the vertical expansion of firms but were originally not adapted to the dynamic setting of industry evolution. These concepts are reviewed in the following section.

Boundaries of the firm

One of the most influential theoretical frameworks dealing with the expansion of firms is the transaction cost theory (Williamson, 1975, 1985). In principle, the transaction cost approach provides an explanation for why firms outsource some value activities but carry out others within their own boundaries. The theory assumes imperfect contracts and opportunistic market participants with bounded rationality. Transactions are associated with certain hazards and are accompanied by costs that are the higher the more insecure and infrequent a transaction is and the more specific the transaction-related investments are (Masten, 1984; Williamson, 1975, 1979). Firms will integrate value activities that are accompanied by high transaction costs and will outsource those activities that entail low transaction costs (Jacobides, 2005; Williamson, 1975, 1985).

In its basic formulation this approach is largely static and assumes that there always exists a choice between an internal or external performance of value activities, although this possibility may not always be given (Cacciatori & Jacobides, 2005; Jacobides, 2005; Malerba et al., 2008).

Langlois (1992) takes a more dynamic view of the approach and analyzes the change of transaction costs over longer periods of time. "If the environment is genuinely one in which change is diminishing, then it is also one in which behavior must be becoming increasingly routine. And routine behavior is necessarily easier to monitor and measure than non-routine behavior. In an environment in which change is absent, the ‘plasticity’ necessary for moral hazard is also absent. For all these reasons, one would expect transaction costs to play a small role in the long run” (Langlois, 1992, p. 104 et seq.). Langlois (1992) does not make any clear statement about the development of vertical structures within an industry but establishes a link to the industry life cycle as this concept assumes a reduction of uncertainty over time as well.

So the growing standardization of product components during the evolutionary course may lead to an increasing tendency of downstream manufacturers to acquire inputs on the market from external upstream suppliers, given that such suppliers exist. Not only the reduced uncertainty does encourage market transactions in later evolutionary phases, but also the reduced specificity of transaction-related investments would no longer require an internal performance of certain value activities to avoid transaction hazards (Argyres & Bigelow, 2007).

Besides the transaction cost theory also the resource-based approach (Barney, 1991) can be used to explain the expansion of firms. Various studies related to this approach have analyzed the optimal boundaries of firms depended on the problems a firm needs to solve (Macher, 2006; Nickerson & Zenger, 2004), the type of innovative activities a firm performs (Teece, 1996; Wolter & Veloso, 2008) as well as the available technological performance of products in relation to market demand (Christensen et al., 2002).

The starting point of Nickerson and Zenger’s (2004) considerations is the decomposability of problems a firm faces. Decomposable problems exhibit a low degree of interactions between different knowledge sets and design choices. Directional search is suited to solve such problems, and markets are best qualified for governing this kind of search. However, due to limited incentives for knowledge exchange and limited possibilities for communication between market participants, markets may be less suitable for solving complex problems. These problems exhibit a high degree of interaction between different knowledge sets and design elements and cannot be divided into individual components. Heuristic or cognitive methods of search are necessary to solve such problems and in general hierarchical structures provide an efficient framework for these search methods (Nickerson & Zenger, 2004).

In the early evolutionary phase customer needs and technological possibilities are highly uncertain and unstable and often the performance of products does not yet satisfy the needs of the mainstream market. Thus, competitive pressure forces companies to merge components in new ways to enhance product performance. The product is not modular at first, as every component depends on the others. So in this period of complex problems, vertically integrated firms have an advantage. However, once the technology reaches a performance level that satisfies the demand of the mainstream market the competitive landscape changes. Now firms will aim for cost reductions and higher development pace and create modular products. Market exchange relationships will be favorable as the types of problems have changed (Christensen et al., 2002).

Macher (2006) finds empirical support for these relationships investigating the development of technology in the semiconductor industry. Poorly structured and complex problems are more likely to be solved internally than through market interactions. Specialized manufacturers have an advantage over integrated firms in terms of speed and quality of problem solutions when facing simpler problems, whereas integrated firms exhibit a higher quality of problem solutions when the problems are more complex.

Teece (1996) analyzes optimal boundaries of firms with regard to different innovative activities. He distinguishes between autonomous innovations that can be carried out without changes of other product components and systemic innovations that entail far-reaching changes to the whole product system. He argues that integrated firms could better deal with systemic innovations compared to specialized firms due to advantages with regard to the necessary flow of information, the required coordination and the removal of institutional barriers.

Wolter and Veloso (2008) analyze on the basis of Henderson and Clark's (1990) typology of innovations the theoretical reaction of firms with regard to their vertical boundaries to exogenous innovative shocks. Whereas no changes of vertical integration are predicted for incremental innovations, incentives for integration are considered to be high for architectural innovations. Since architectural innovations change the linkages of the different product components and create new dependencies, coordination of the adjustments to achieve a fit between the new architecture and customer needs gains significant importance. This coordination can be performed best within an integrated firm. For modular innovations destroying only upstream technological competencies but not the product architecture as well as for radical innovations affecting all previous competencies, incentives for both integration and disintegration are given. However, Wolter and Veloso (2008) argue that disintegration incentives might be higher in the case of modular innovations and integration incentives might dominate in the case of radical innovations.

Combining these insights with industry life cycle concepts with rather architectural or systemic innovations being predominant before the emergence of the dominant design and autonomous, incremental innovations thereafter supports the idea of vertical disintegration in the course of industry evolution.

With the tendency of vertical disintegration being explained by different theoretical concepts an important question remains, when exactly vertical disintegration will take place, as firms for the production of specialized inputs usually do not exist from the onset of an industry (Cacciatori & Jacobides, 2005; Jacobides, 2005). Within the context of a service industry Jacobides (2005) develops two necessary conditions that must be met in order to enable vertical disintegration: (1) coordination simplification and (2) information standardization. Only the reduction of interdependencies along the value chain will allow for a separation of individual activities and only standardized information will permit contracting parties to describe and control market transactions. Intra-firm partitioning of administrative tasks as well as benefits from inter-firm co-specialization are enabling processes for these two conditions to be reached (Jacobides, 2005).

In the context of a product industry, however, this process might not be so gradual. With many different products with different architectures being present on the market in early evolutionary phases specialized suppliers would face high transaction-specific costs as they would be able to sell specific components only to one or a few downstream manufacturers. Moreover, the technology of the product first might be so crudely understood that downstream manufacturers are unable to outsource the production of certain components at all. When coordination simplification and information standardization are necessary conditions for vertical disintegration, only the occurrence of a dominant design will provide the basis for these conditions. This leads to the prediction that markets for specific upstream inputs and specialized supplier populations will only emerge with the convergence towards a dominant design. This relationship is elaborated in the following model.

A model of the evolution of vertically related populations in an industry

Usually a radical innovation gives rise to a new industry. Numerous new firms enter the market with diverse product variations. Systemic product innovations with high interdependencies between design features gradually increase the functional performance of the technology until it corresponds to the demand of the mainstream market. Due to the non-decomposability of problems and lacking legitimacy, integrated downstream end-product manufacturers following '*r*-strategies' have an advantage. Moreover, the poor level of legitimacy and the high level of uncertainty due to the lack of a dominant design may not provide opportunities for specialized suppliers obstructing the emergence of markets for inputs (Hunt & Aldrich, 1998). However, with progress in the evolutionary course, increasing standardization and gradual decomposability of problems lead to an increasing specialization of functions within firms. Tendencies of disintegration become apparent, although only the convergence towards a dominant design lays the foundations for coordination simplification and information standardization and subsequently for the formation of specialized suppliers and markets for the exchange of upstream inputs. A high number of specialized suppliers rush into the industry and downstream manufacturers outsource standardized value activities to these suppliers in order to achieve cost reductions. Downstream manufacturers not producing the dominant design will be unable to achieve a sufficient reduction of unit costs with efficiency orientated '*K*-strategies'. Together with other less capable firms they are forced to exit the industry. A 'shakeout' may occur in the population of downstream manufacturers that may be followed by a 'shakeout' in the supplier population as the remaining large downstream manufacturers may only rely on a few large upstream suppliers with which they have already established stable exchange relationships. Figure 1 provides an overview of the developed model.

INSERT FIGURE 1 ABOUT HERE

It seems important to note that research has shown that the magnitude of the 'shakeout' in the downstream manufacturer population will depend on the extent and type of vertical disintegration (Bonaccorsi & Giuri, 2000; Klepper, 1997). Specialized suppliers may create new niches for specialized end-product manufacturers stimulating the entry of new firms. This will especially be the case when fragmentation of customers of the final product is high (Klepper, 1997). Furthermore, the separation of value activities may alter the appropriability conditions of the technological regime and prevent a 'shakeout'. This can happen when the need for cost-efficient production shifts from the downstream population to the upstream population thus displacing an industry from its natural trajectory (Bonaccorsi & Giuri, 2000).

Following the phase of disintegration – with or without a ‘shakeout’ – downstream manufacturer and upstream supplier populations eventually enter a more stable stage of evolution that may be terminated by a radical innovation or the complete displacement of the industry.

The model does not preclude that some suppliers are present well before the convergence towards the dominant design, particularly when these suppliers originated in other industries that already entered an advanced evolutionary phase. Such firms may well provide certain inputs for the new industry that are however predicted to be rather general.

3. The German Piano Industry

Analyses and procedures

The paper now first presents a detailed case study of the evolution of the technology of the piano instrument and of the German piano industry including demographic data on all known German piano manufacturers and suppliers. The case study is then later related to the developed evolutionary model. Numerous archival sources and industry publications served as the basis for the review of the instrumental and industrial history. Especially Cieplik (1923), Bethmann (1929), Euting (1931), Freygang (1949), Henkel (1994), Heyde (1994), Speer (2000) and Dürer (2003) contributed to an in-depth understanding. Demographic data on German piano manufacturers and German supplier firms were gathered from Henkel (2000, 2002, n. d.). Henkel himself primarily used the issues of the so-called ‘Welt-Adressbuch der gesamten Musikinstrumenten-Industrie’, an industry directory of the music industry, as well as diverse volumes of various industry specific periodicals for the compilation of the manufacturers’ histories. Besides that, more than 190 further sources were consulted for his 'Lexikon deutscher Klavierbauer' (Henkel, n. d.). According to Henkel (2000, p. 5) his encyclopedia contains all German manufacturers of hammer pianos traceable either through preserved instruments or literary pieces of evidence. The 'Lexikon deutscher Zulieferbetriebe für die Klavierindustrie', an encyclopedia on all suppliers, serves as supplement and contains all traceable supplier firms (Henkel, 2002).[1]

The history of the piano instrument

The term 'piano' refers to stringed keyboard instruments whose strained strings are caused to vibrate by strikes of hammers via a claviature and an action and whose tones are emitted by a soundboard (Henkel, 1994, p. 123). The name 'piano' emerged as short term for 'pianoforte' and describes a musical-tonal characteristic of pianos: the action of a piano allows for both a 'soft' ('piano') and a 'loud' ('forte') playing of the tones (Freygang, 1949). Nowadays, two construction types of pianos have become dominant: the 'upright' version and the wing-shaped version called 'grand piano'. As there are no fundamental differences between building grand pianos and uprights (Cieplik, 1923, p. 41), a uniform delimitation of the industry appears to be appropriate.

The ancient origin of the piano is the musical bow developed into various types of polychords and brought to Europe by the Arabs (Lechner, 2006; Neupert, 1971). The further advancement to stringed keyboard instruments paralleled the development of polyphonic vocal music in the 14th century. Keyboards were already known from organs, which started to spread all over Europe in

[1] Henkel (2000, 2002, n. d.) provide the industry tenure for each producer. Often industry tenure is determined by the first and/or last literary evidence in one of the sources. In most cases, a producer could ultimately be detected in the last edition of the ‚Welt-Adressbuch der gesamten Musikinstrumenten-Industrie' in 1929 (Henkel, 2000, 2002). In some cases producing entities were transferred to new owners, which were themselves not traceable as independent producers before. Different entries for those firms in Henkel's encyclopedias (2000, 2002) were consolidated. Known takeovers by already traceable firms as well as firm dissolutions by owners that immediately started their separated own businesses were treated as censored cases. As a general rule, Henkel's (2000, 2002, n. d.) direct indications were followed to code industry entry and exit dates. However, if more precise or deviating details in the remarks about a specific producer were available, adjustments have been undertaken. Non-producing labels have not been taken into account.

the 9th century. Those keyboards were then combined with polychords, resulting first in the so-called clavichord (Lechner, 2006). The development of the harpsichord followed around 1440. When striking a key on the keyboard the strings of these instruments are plucked by a plectrum (Henkel, 1994; Restle, 2000). Harpsichords had their period of glory in the era of baroque music during the 17th and early 18th century as part of the so-called 'basso-continuo' (Lechner, 2006). Due to their mechanism of sound generation that does not allow for dynamic changes of the volume harpsichords have a rather static sound (Henkel, 1994).

The Italian music of the late 17th century, however, with large string orchestras and new tonal finesses called for the development of a new stringed keyboard instrument enabled to play crescendos and decrescendos (Restle, 2000). The most important innovation is attributed to the Florentine harpsichord builder Bartolomeo Cristofori, who developed the first hammer piano action at the court of Ferdinando de' Medici in 1698 (Hollfelder, 1999; Lechner, 2006). Other early models of hammer actions by Jean Marius in Paris in 1716 or by Christoph Gottlieb Schröter in Dresden in 1717 were soon forgotten (Adlam, 1983). Cristofori developed his action further into the so-called escapement action. The escapement was obtained "by a centred lever (…) or hopper, working, when the key is depressed by the touch, in a small projection from the centred hammer-butt" (Hipkins & Schlesinger, 1910/11, p. 565). Gottfried Silbermann, a German organ builder from Freiberg, copied Christofori's action and later around 1733 presented one of his pianos to Johann Sebastian Bach (Henkel, 1994). Bach – as it has been reported – shall have praised the sound in general but also claimed that the sound was too weak in the descant and that the instrument was too difficult to play (Kentner, 1982). Christofori's escapement action was then further developed first in Saxony and later, when Saxon instrument builders emigrated to England, predominately there. This led to the so-called 'English action', which was later also built in France (Adlam, 1983; Henkel, 1994).

Parallel to the improvement of the escapement action the so-called ‘Viennese action’ was developed, first in Germany and later especially in Austria. The Viennese action contrasts with the escapement action as it differs in its arrangement and its mechanism to move the hammer. Since the 1720s this type of action was used especially in square pianos, which were built as rectangular cases with horizontally arranged strings diagonally to the keyboard. Most of these actions were implemented in a way that the strings were struck by the hammers from below, but first also down-strike actions existed especially in Saxony. However, due to several disadvantages down-strike actions were short-lived (Lechner, 2006).

At the end of the 18th century two separate design paths evolved, which co-existed for some time (Good, 2003; Kentner, 1982). Compared to the English action, the Viennese action was responsively light and subtle enabling a virtuous playing with high precision of the works of Haydn, Mozart and other important German composers (Good, 2003; Henkel, 1994). Contrarily, the English action was especially important for works of Clementi and his students as well as of Beethoven (Neupert, 1971). It had a loud orchestral sound but was cumbersome in its stroke as the key had to be hit with certain pressure and it was slow in repetition as the key had to completely come back to its initial position before a new strike of the hammer was possible (Adlam, 1983). This, however, changed with an innovation by Sébastien Érard in Paris in 1808. A complex system of fine levers made it possible that the hammer did not have to come back to its initial position before the next strike could be provoked. Further developments led to the so-called double escapement action patented by the Érard brothers in 1822 (Adlam, 1983; Lechner, 2006). The double escapement action combines the sonority of the English action with the fast responsiveness of the Viennese action (Good, 2003).

Besides the advancement of the action, there was a range of other innovations, of which some prevailed in the long run and others not. Around the turn of the 18th and 19th century several registers especially in grand pianos were deployed (Neupert, 1971). Initially these registers were operated by hand. Later experiments were made with knee levers but eventually pedals to control the registers took hold (Adlam, 1983; Henkel, 1994; Neupert, 1971). Also for the dampers different types developed before the current standard was established (Henkel, 1994).

Towards the end of the 18th century the piano almost fully replaced the harpsichord. Socio-economic trends of the 19th century spurred not only piano production, but also led to further design changes. It was the time of a rising middle class and rapid industrial development. New concert halls were built and music and instruments were no longer reserved just for the clergy or nobility. The piano was especially suited to re-play music at home leading to a higher demand for smaller, more space-saving models. Early attempts of building upright pianos date back to the early phase of the industry. Further attempts in Dublin, Philadelphia, London and Vienna led to so-called ‘cabinet pianos’ and ‘cottage pianos’. But eventually, Robert Wornum invented a suitable adjustment of the action in 1826 which was the birth of the modern upright. It completely displaced the square piano by around 1860 (Good, 2003; Neupert, 1971).

The more compact version was accompanied by cross-stringing, where the bass strings were arranged diagonally over the other strings, invented by Henri Pape in Paris in 1828. The trend to bigger orchestras also called for louder pianos with a larger tonal range (Good, 2003). However, louder sound meant multiple stringed tones and highly screwed strings. A larger tonal range meant even more strings all resulting in high mechanical pressure (Henkel, 1994). Piano builders first used metal bracers to support the wooden frames but soon experimented with iron frames and metal plates leading to the first full cast iron frame patented in Boston by Alpheus Babcock in 1825 (Adlam, 1983; Good, 2003). Other important innovations in the 1820s included the use of cast steel for the strings and felted hammer heads (Hollfelder, 1999; Lechner, 2006).

Louder sound and more solid hammers let later versions of the Viennese action work more and more sluggishly, so that it was decreasingly employed and finally completely abandoned by around 1900 (Henkel, 1994; Lechner, 2006). Until 1870 basically every large piano manufacturer had its own, often patented action but then the Érard-Herz-action produced by specialized suppliers prevailed (Henkel, 1994; Neupert, 1971).

All major innovations on the way to the modern piano were made until the early 1850s. The last step to a standardized design was then rendered by Henry Steinway (Restle, 2000). He was the son of the German instrument builder Heinrich Steinweg who founded the company Steinway & Sons in 1853 after immigrating to the U.S.A. (Henkel, 2000). Henry Steinway experimented early with the innovations from Europe and the U.S.A. and developed them further. Eventually, he employed them all together in one instrument (Lieberman, 1995). "The so-called Steinway system included all Henry's achievements: a cast iron plate with a downward projecting flange, longer and heavier over-strung bass strings fanning out over the center of the soundboard, a vibrant soundboard with the bridges closer to the center, and a responsive action that gave performers more control over the new power at their fingertips. Some of these things were his own invention, some the result of heavy borrowing from others. (…) This was the modern piano, and it has not changed much since 1859. By the end of the century most of the major piano manufacturers in the United States and Europe were imitating Henry's construction, and all pianos today use the Steinway system" (Lieberman, 1995, p. 26).

Later innovations were confined to some minor technical features or the use of some new improved materials like artificial glues or plastic (Good, 2003; Restle, 2000). One development that had some influence for a short period in the early 20th century was the mechanically played piano. It used a pneumatic action and played songs on its own, which were for example recorded on punched paper tape. However, the breakthrough of the radio and the record rapidly ended the florescence of the pneumatic piano (Good, 2003; Speer, 2000). Those developments also had profound effects on the production of traditional pianos. Whilst the piano initially had experienced an enormous impetus through the rise of the middle class, changed leisure time activities, the invention of the gramophone as well as the automobile replacing the piano as a status symbol were reasons for the end of the period of glory of the piano (Speer, 2000).

The history of the German piano industry

In Germany, the first piano makers entered the industry in the early 18th century (Henkel, 2000). Nearly all of them were located in big cities with universities, the bishop seat or the seat of the court (Speer, 2000). The first piano builders were mostly organ builders, carpenters or cabinet makers as the profession of instrument builders at that time was closely related to these other basic occupations (Heyde, 1986). Pianos were often only produced as side products (Henkel, 1994). Moreover, the local rules of the guilds contributed to this combination, as for example only carpenters that were members of the respective guild were allowed to perform joineries (Speer, 2000). Even in big cities there were seldom enough instrument builders to form an own guild (Moeck, 1987).

Only from 1780 onwards piano manufacturers were able to make a living with the sole production of pianos (Henkel, 1994). The production, however, was small as there were only few sales opportunities. The craft producers often were family businesses with rarely more than three workmen producing for the local market (Dürer, 2003; Henkel, 1994; Heyde, 1986). Around 1800, about 200 German piano producers but basically no suppliers were traceable (Henkel, 2000, 2002, n. d.). Figure 2 displays the evolution of the population of German piano manufacturers, figure 3 shows the evolution of the (combined) supplier population.

INSERT FIGURE 2 ABOUT HERE

In the early 19th century the number of small piano manufacturers grew considerably. At that time some of them were also located on the countryside but still most of the firms operated only locally and did not gain greater importance (Speer, 2000). The most important centers of the global piano industry were outside Germany. Vienna, London and Paris had an excellent reputation due to their high quality instruments and were also popular destinations for German journeymen during their travel years (Clinkscale, 1999; Speer, 2000).

Unstable political conditions with the Napoleonic Wars, continuously changing tariff barriers of the German states and territories, the existing guild system as well as foreign instruments flooding the German market were seen as barriers for a rapid rise of the German piano industry (Cieplik, 1923; Heyde, 1986; Speer, 2000). These conditions also may have been a reason for many prominent German piano builders at that time to emigrate to cities like London, Vienna, Paris or New York (Henkel, 2007).

During the first half of the 19th century Austria became the most important piano exporter with Vienna as the global capital of music and home to many famous composers and piano manufacturers (Cieplik, 1923). Viennese instruments were considerably cheaper to build and to maintain compared to the English ones due to their construction. Therefore, Viennese pianos also were better saleable and many German piano builders imitated the Viennese instruments to create a sound economic foundation for their businesses. High import tariffs sealed the Austrian market off from foreign products which hindered Austrian manufacturers to observe innovations in other countries and slowed down technological progress of their instruments (Henkel, 2007).

A gradual liberalization of the guild and commercial regulations (Henning, 1978), the fall of tariff barriers due to the establishment of a single market with the German Customs Union (‘Zollverein') as well as the advancement of the infrastructure eliminated major restrictions for the development of the German piano industry. Since the 1840s production more and more was conducted in factories characterized by a division of labor and serial production (Speer, 2000). The first specialized German supplier for actions was founded in 1835 in Gera followed by the first supplier of claviatures in Leipzig in 1843 (Henkel, 2002).

In 1850, about 380 German piano manufacturers and about 70 German supplier firms but only seven specialized action or claviature producers existed (Henkel, 2000, 2002, n. d.).

INSERT FIGURE 3 ABOUT HERE

Still in the first half of the 19^{th} century Austrian instruments began to lag technologically behind and were driven out of the market first by English and French products (Speer, 2000). But soon this trend also affected English and French instruments (Heyde, 1994; Speer, 2000). Contrary to Austrian, English or French producers, the German piano industry was quick in the adoption of all kinds of improvements and eventually of the dominant design and displaced the once famous industries in the other countries (Cieplik, 1923; Heyde, 1994; Speer, 2000).

The world exhibitions in London in 1851 and Paris in 1855 set the foundation for the export orientation of the German piano industry (Cieplik, 1923; Speer, 2000). By 1860, 425 piano manufacturers and 107 suppliers including 11 claviature and action producers existed with Berlin as the new center of the German piano industry (Henkel, 2000, 2002, n. d.; Speer, 2000).

Smaller craft producers were now forced to exit the market as they were unable to compete with larger industrial factories (Speer, 2000). At the same time specialized suppliers gained more and more importance, which supported the development of cost-effective mass production (Cieplik, 1923; Dürer, 2003). This led to the rise of numerous firms especially in Berlin producing low-quality commercial pianos by simply assembling the different inputs (Dürer, 2003; Speer, 2000).

Soon a general classification system of pianos was developed sorting the products into three different categories: high-quality branded pianos, medium priced quality pianos and cheap low-quality commercial pianos (Freygang, 1949).

The most important supply products were claviatures, piano actions and cast-iron plates. Claviature producers themselves sourced from ivory and other key covering firms as well as from semitone producers. Piano action manufacturers sourced from felt and leather producers, piano hammer and hammer head manufacturers. Other specialized firms supplied piano bridges, rests, soundboards, wood and wooden articles, strings and bass strings, metal goods, woven fabrics, glues, lacquers, mordant as well as other products (Euting, 1931; Freygang, 1949; Henkel, 2002).

Figure 4 separately displays the evolution of five aggregated subpopulations of suppliers according to their potential importance for the piano manufacturer population. Whereas basically all piano producers sourced claviatures, actions and cast-iron plates from specialized suppliers after the convergence to the dominant design, high-quality manufacturers produced other inputs mostly internally for quality reasons (Freygang, 1949).

INSERT FIGURE 4 ABOUT HERE

The world exhibitions in London in 1862 and Melbourne in 1880 further increased the export success of the German piano industry (Cieplik, 1923). From 1880 to 1909 about 2,650,000 instruments were produced of which about 55% were exported (Henkel, 1994). Great Britain and its colonies, especially Australia, became vital sales territories for the German piano industry but also Russia with Finland and other European countries as well as countries in Central and South America imported mostly German pianos (Cieplik, 1923). Total production peaked in 1913 with about 172,000 pianos produced (Freygang, 1949). In this year before World War I 541 piano manufacturers and 574 suppliers existed (Henkel, 2000, 2002, n. d.).

World War I was an incisive event for the German piano industry as especially at the beginning the industry was completely cut off from its foreign sales territories and also domestic demand for luxury products such as the piano was limited. The piano industry lost many of its qualified employees to the military service or to the defense industry. Moreover, shortage of materials caused some firms to change their production to military goods as well (Cieplik, 1923).

After World War I sales conditions remained difficult. Earlier export countries had begun to establish their own piano industries and import restrictions and high tariffs made it difficult to increase sales figures (Cieplik, 1923). Nevertheless, especially small and medium sized firms entered the industry after the war in the hope of currency gains during a time of hyperinflation. However, most of these ventures were short-lived (Cieplik, 1923; Henkel, 1994). In 1926, a peak in the number of piano producers was reached and nearly 810 piano manufacturers as well as about 670 suppliers with more than 60 claviature and action producers existed (Henkel, 2000, 2002, n. d.).

But then technical advances, such as the invention of the gramophone and radio, changed leisure time activities together with the following Great Depression revoked the means of existence of the German piano industry (Speer, 2000). From 1929 to 1933, production declined by more than 90% (Freygang, 1949) and most piano manufacturers and suppliers could ultimately be detected in the last edition of the industry directory published by Paul de Wit in 1929 (Henkel, 2000, 2002, n. d.).

World War II further intensified the difficult situation. Again materials were lacking and many factories closed or changed their production to military goods (Dürer, 2003). After the war the division of Germany negatively impacted firms in Eastern Germany, who had to resort to low-quality inputs. Also in Western Germany the lack of capital first prevented a quick recovery after the war. From the 1950s onwards production again increased but soon was repelled by Asian imports of cheap pianos. The German reunification led to a re-privatization of many traditional factories in East Germany. However, the fall of the Iron Curtain flooded the German market with cheap products from Poland, Russia and Czechoslovakia. German producers tried to react with cost reductions but many were forced to leave the industry. In recent years a rethinking seems to have taken place and the few remaining producers try to produce high-quality pianos delivering a good value for money (Dürer, 2003). “The German piano industry today is prestigious not because of the number of instruments manufactured, but because of its significant history and the superior quality of its instruments” (Dürer, 2003, p. 153).

The following section now discusses to what extent the evolution of the German piano industry reflects the presented model of the evolution of vertically related populations in an industry.

4. Analysis of the Evolution of the German Piano Industry

The technological development of the instrument exhibits a very good fit with the theoretical concept of the industry life cycle (Abernathy & Utterback, 1988; Klepper, 1997). The disruptive invention (Christensen et al., 2002) of the escapement action by Cristofori in 1698 triggered the industrial life cycle. The emerging products initially did not meet the requirements of the mainstream market, as they were either tonally too weak or not easy enough to play. Further, the pianoforte and its manufacturers first needed to gain legitimacy compared to the organ or the harpsichord and pianos were produced only as side products. Numerous experiments, with mostly systemic (Teece, 1996) or architectural innovations (Henderson & Clark, 1990) characterized the early development. The competition between the soft, responsive Viennese and the heavy English action resulted in many different products with diverse registers, types of damping and tonal ranges, all strongly targeted at different customer segments and music from different composers.

At this time the implementation of a new and improved component normally required an adaptation of the whole system. German producers experimented with the different construction types, often created a means of existence by building cheaper and simpler Viennese pianos (Henkel, 2007) but also imitated the more sophisticated English instruments (Heyde, 1994). Copying and imitation were quite common in early periods of the industry either by the purposeful visit of industrial exhibitions and sometimes even the reverse engineering of foreign instruments or by the exploitation of knowledge acquired as a journeymen abroad (Heyde, 1994; Speer, 2000). However, this required a broad knowledge base and a common language for sharing this knowledge that is best created within the firm's own boundaries (Nickerson & Zenger, 2004). Moreover, technological competition was additionally favored by the relatively weak appropriability regime for innovation rents at that time (Hoehl, 2003), making integration for companies in the early evolutionary phase even more advantageous. As integration limits the exchange of information with external firms it can reduce problems associated with the outflow of knowledge (Teece, 1996).

In line with the model's prediction in the early evolutionary phase most manufacturers were completely integrated firms producing all components on their own (Henkel, 1994). This phase also saw an increase in the number of downstream manufacturers with suppliers being virtually non-existent as figure 6 shows.

INSERT FIGURE 5 ABOUT HERE

The linkage and advancement of several existing innovations into one instrument by Henry Steinway and, hence, "synthesized from individual technological innovations introduced independently in prior product variants" (Utterback & Suarez, 1993, p. 1) resulted in the dominant design in 1859. In line with theoretical predictions (Utterback & Suarez, 1993), manufacturers especially in Austria, France and England that ignored the dominant design were forced to exit the industry, whereas the German piano industry quickly adopted it and started to flourish (Bethmann, 1929).

In conformity with the model, at around the same time a disintegration of the industry took place and the number of specialized suppliers increased sharply. The process of specialization involved three steps: First, the gradual intra-firm division of labor. Second, a particular stage of this intra-firm division of labor led to a disintegration of the production of certain product components. Third, the introduction of steam powered engines led to industrial piano factories in a narrower sense. A considerable developmental step was the formation of specialized action and claviature producers (Heyde, 1994, p. 129). This corresponds with the predictions made by Jacobides (2005), according to which intra-firm partitioning of administrative tasks as well as benefits from inter-firm co-specialization are enabling processes for vertical disintegration. The formation of the first specialized German action producer in 1835 happened only after the invention of the double escapement action in 1822 which became an integral part of the dominant design. This again is consistent with the prediction that coordination simplification and information standardization are prerequisites for vertical disintegration (Jacobides, 2005) and that only the convergence to the dominant design enables those prerequisites to be met.

After the establishment of the dominant design, only incremental improvements were made. The design's basic principles, however, remained unchanged. Therefore, in the case of minor autonomous innovations, piano manufacturers no longer needed to make modifications to the whole system, which allowed for exchange relationships on markets and benefited disintegrated firms (Macher, 2006; Teece, 1996; Wolter & Veloso, 2008). Accordingly, from around 1870 onwards basically all downstream manufacturers sourced their actions but also other components externally from specialized suppliers (Henkel, 1994).

The fact that a 'shakeout' did not appear after the convergence to the dominant design might have been due to two factors. First, the weak foreign piano industries opened up growing export opportunities for German manufacturers resembling an expansion of the resource space enabling more firms to exist in the industry. Second, the disintegration of value activities along the industry's value chain with the formation of specialized suppliers using capital-intensive special-purpose machines and producing product components cost-efficiently at high volume (Cieplik, 1923; Dürer, 2003) allowed also smaller piano manufacturers to purchase necessary inputs at low cost. This enabled also smaller firms to exist in the market (Euting, 1931). So as economies of scale primarily affected input suppliers but not downstream manufacturers, the disintegration changed the appropriability regime and with it the natural trajectory of the industry (Bonaccorsi & Giuri, 2000). Only fundamental changes causing the massive reduction of environmental resources for the piano industry lead to the dramatic 'shakeout' after 1929 in both populations downstream manufacturers and upstream suppliers.

The following chapter summarizes the results of this study and discusses implications, limitations as well as further avenues of research.

5. Conclusion

In the past decades, research on the evolution of industries and organizational populations has led to diverse theoretical models and perceptions about the co-evolution of categories, technologies and innovations, the orientation of research and development as well as legitimation and competition with industrial dynamics and the demographic composition of organizational populations (Carroll & Hannan, 2000; Klepper, 1997; Nelson, 1994; Núñez Nickel & Moyano Fuentes, 2004; Suarez et al., 2014; Utterback & Abernathy, 1975). However, in all these models little attention has been devoted to the vertical structure of companies along an industry's value chain and the change of this structure over time (Jacobides, 2005; Klepper, 1997). This study built on previous research on industrial life cycles and theoretical concepts dealing with the vertical boundaries of firms and developed a model of the evolution of vertically related populations in an industry. Combining compiled conditions enabling vertical disintegration with the typical evolutionary trajectory of product industries it is predicted, that initially only integrated downstream manufacturers will exist. Due to high uncertainty, poorly understood technologies, systemic innovations and various different product designs with various functionalities present there will be no opportunities for specialized suppliers to enter the industry. With decreasing uncertainty and less complex problems for firms to solve disintegration incentives will increase. However, only the convergence towards a dominant design will enable to meet the necessary conditions for vertical disintegration and market formation, namely coordination simplification and information standardization (Jacobides, 2005).

A case study of the evolution of the German piano industry including detailed quantitative demographic data on the populations of German piano manufacturers and German suppliers to the piano industry conforms to the theoretical model. A considerable emergence of suppliers only set in with the occurrence of the dominant design. The ongoing expansion of the resource space due to increasing exports as well as a shift of the efficient production towards upstream suppliers initially impeded a 'shakeout' in the populations that only appeared with fundamental changes that revoked the means of existence of the industry.

The study contributes to the existing literature by developing a holistic theoretical model of the dynamic development of vertically related populations along an industry's value chain and therefore closes a gap in previous models dealing with the evolution of industries. The investigation allows for important conclusions on the relation between industry evolution and vertical differentiation as well as on the emergence of markets and the demographic development of vertically linked organizational populations in an industry. It also emphasizes the considerable importance of the dominant design in industry evolution. “A lack of standard designs, for example, may block the diffusion of knowledge and understanding, thus constraining […] new activities” (Hunt & Aldrich, 1998, p. 287). In the piano industry adopting the dominant design quickly yielded great advantages for German piano manufacturers including increasing export opportunities at the expense of foreign piano builders and a higher survival rate partly due to the emergence of important specialized suppliers (Stürz, 2014). This means that the enforcement of industry standards can represent an important contribution to growing legitimation leading to an improvement of environmental and survival conditions especially for new firms in new industries (Hunt & Aldrich, 1998).

One limitation of this study is that the German piano industry is an old and special industry with own regularities. The heterogeneous development of the piano industry in different countries already points out that historical coincidence, political influences and other external conditions play an important role in the evolution of industries (Jacobides, 2005). For example, the political and cultural conditions with the guilds in the early evolutionary phase of the industry provided incentives for integration which were not driven by the type of innovations or problem complexity.

Further research should therefore be conducted linking the model to other industries. A more detailed investigation of micro processes governing the vertical disintegration of industries is another further avenue of research (Jacobides, 2005).

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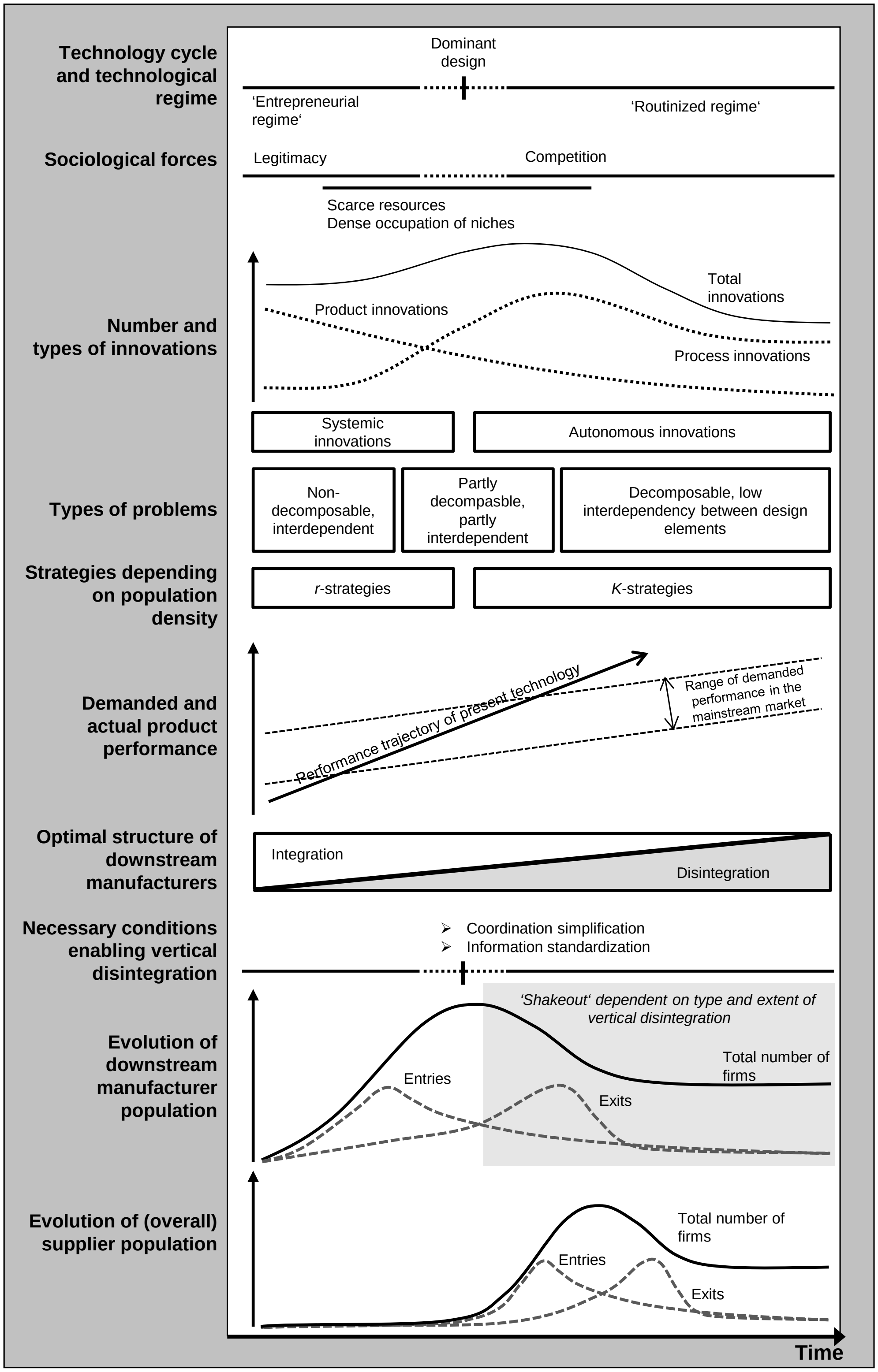

Figure 1: Model of the evolution of vertically related populations in an industry
(Based on graphical elements from Münter (1999, p. 149) and Christensen et al. (2002, p. 961) and theoretical considerations from Brittain & Freeman (1980), Teece (1996), Hunt & Aldrich (1998), Bonaccorsi & Giuri (2000), Carroll & Hannan (2000), Nickerson & Zenger (2004) and Jacobides (2005))

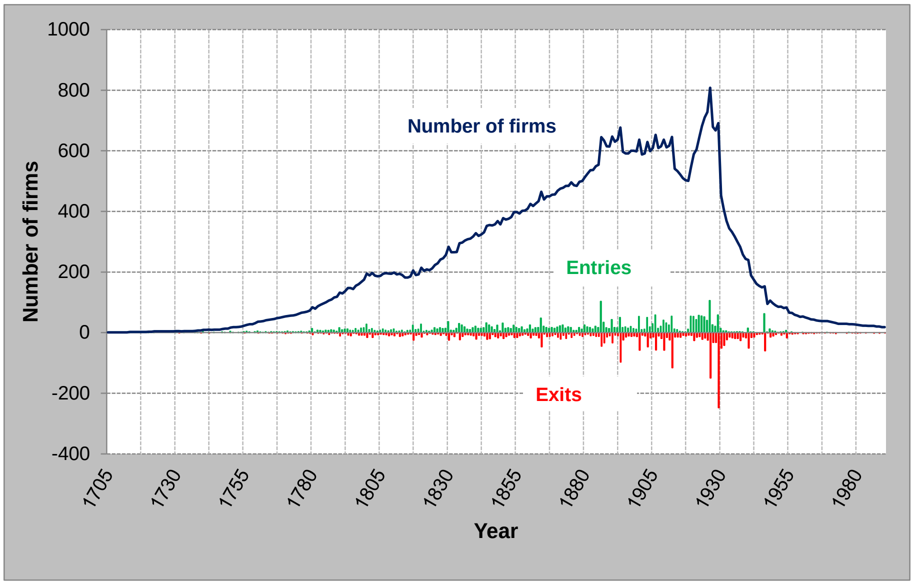

Figure 2: Number of firms and industry entries and exits of German piano manufacturers
(Source: own illustration based on data collected from Henkel (2000, n. d.))[2]

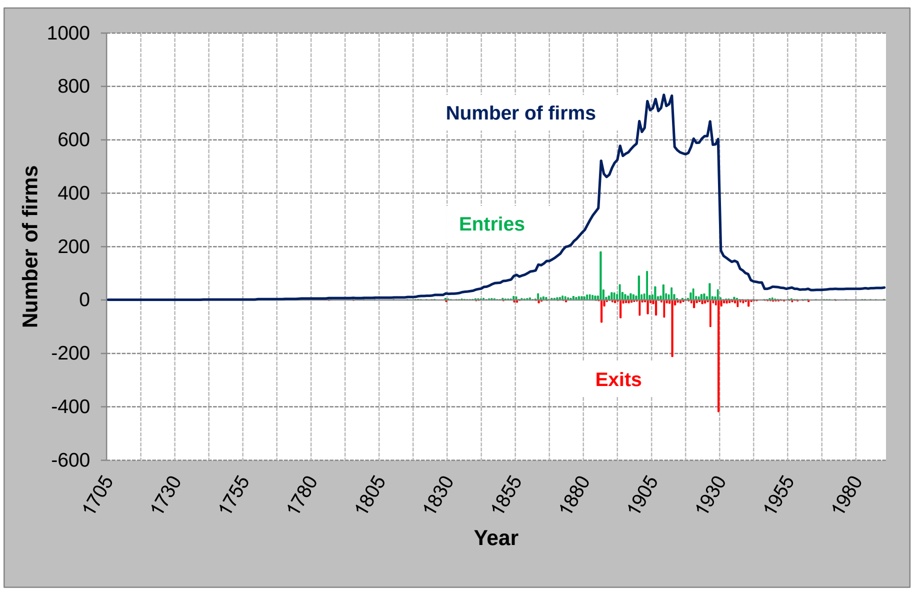

Figure 3: Number of firms and industry entries and exits of German suppliers to the piano industry
(Source: own illustration based on data collected from Henkel (2002, n. d.))[2, 3]

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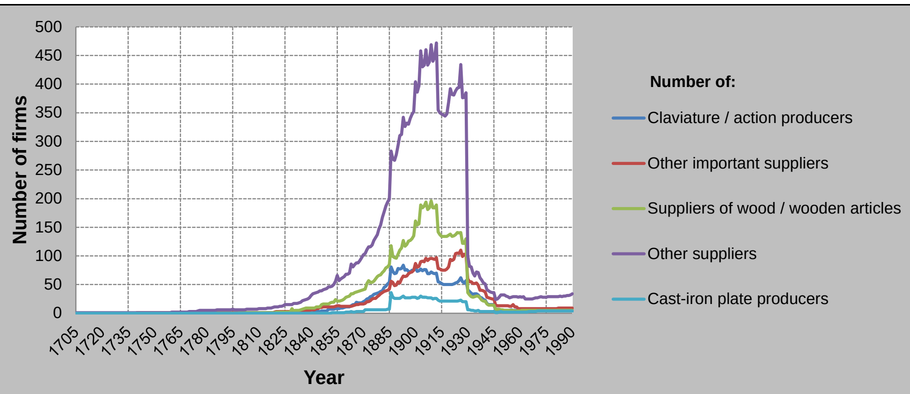
[2] Industry tenures of firms that continued to exist after 1945 in East Germany or East Berlin have been treated as censored cases and are thus not part of the exit counts. Accumulations of industry entries and exits in the years 1886/87, 1893, 1900, 1903, 1906, 1909, 1912, 1926 and especially 1929 are due to the publication of the 'Welt-Adressbuch der gesamten Musikinstrumenten-Industrie' from Paul de Wit in those years. In many cases this publication provides the first and the last evidence of a manufacturer (Henkel, 2000, 2002).

[3] Every supplier here is counted once, independent of the produced supply products. Double counts in both populations for producers that were traceable as piano manufacturers as well as suppliers to the piano industry are thus possible.



Supplier subpopulation:	Description:	Suppliers (supply product types) included:
Claviature / action producers	• Most important supplier subpopulation of core components for all piano manufacturers (Bethmann, 1929; Freygang, 1949)	• Claviatures • Piano actions
Other important suppliers	• Direct suppliers to claviature / action manufacturers and of other important intermediate goods • Less important than claviature / action manufacturers • Potentially close link to piano producers	• Ivory and other key coverings • Felt factories, piano leather, felt & leather stores • Semitone producers • Hammer head producers / repairers, piano hammer producers • Piano bridge producers • Rests, soundboards, piano conversions
Suppliers of wood / wooden articles	• Suppliers of the most important base material, if applicable partly prepared • Potentially close link, especially to manufacturers of cheap low-graded commercial pianos (Freygang, 1949)	• Wood and veneer dyers, wood impregnating plants • Wood, veneer stores, sawmills, veneer cutteries (possibly including wood dyers) • Wood benders, wood embossing firms • Wooden article, wooden sculpture firms (possibly including wood dyers, wood bending firms) • Key blocks
Other suppliers	• Diverse supplier firms and stores • Potentially least important to piano manufacturers	• Architects, designers, drafts for cases, graphic art institutions, catalogue printers, clichés • Bass strings, string spinning mills • Lead wire and lead plug producers • Chenille and silk bristles • Glass coasters, glass company nameplates, glass fillings • Stores for component parts of all sorts • Inlays, company nameplates, medals • Piano blankets, woven fabrics • Piano cases • Piano chairs, chair seats • Piano chair spindles • Constructions, models, separations • Lacquer, mordant producers (possibly including stores), shellac stores • Glue producers for the piano industry • Metal goods, piano candlesticks, piano rolls • Back wall gauzes and fabrics • Strings (wire drawing firms) • Workshops for bronzing, painting and gilding of boards and frames • Tooling equipment • Other component companies
Cast-iron plate producers	• Specific supply product • Manufacturers of cast-iron plates normally produced a variety of products for other industries as well (Freygang, 1949)	• Cast-iron plates

Figure 4: Population densities of five separated subpopulations of German suppliers to the piano industry (Source: own illustration based on data collected from Henkel (2002, n. d.))[4]

[4] Single supplier types are widely corresponding to Henkel's (2002, p. 280) classification. In principle, suppliers can be included more than once (also within one of the five subpopulations) in the counts, depending on their produced supply goods. It has been taken into account if different supply products were traceable at different points of time.

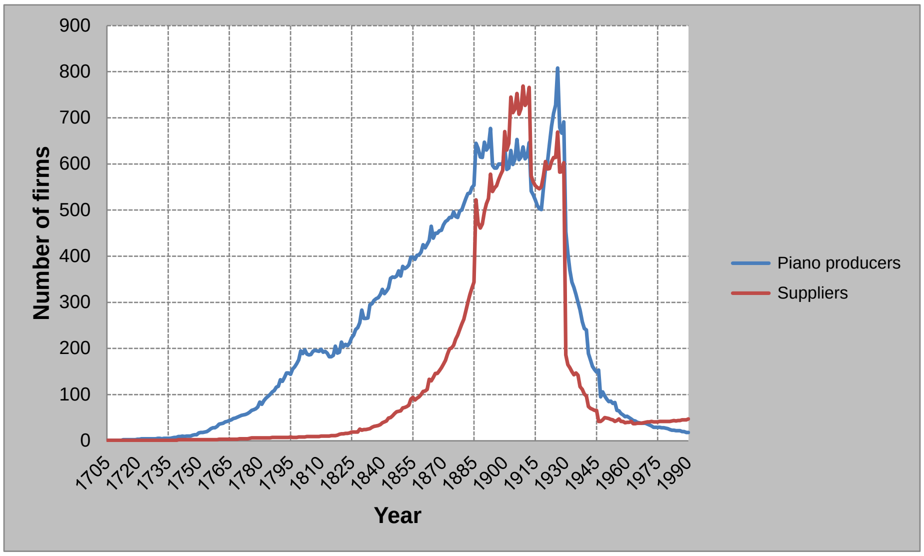


Figure 5: Number of firms of German piano producers and German suppliers to the piano industry
(Source: own illustration based on data collected from Henkel (2000, 2002, n. d.))[5]

[5] Every downstream manufacturer and supplier here is counted once, independent of the produced supply products. Double counts in both populations for producers that were traceable as piano manufacturers as well as suppliers to the piano industry are thus possible.