Different trajectories of industrial evolution

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Different trajectories of industrial evolution: demographical turnover in the European motorcycle industry, 1885-1993

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Abstract

Technological innovation is widely considered as one of the most influential determinants of industry evolution. Along this line of inquiry, the seminal work of Tushman and Anderson (1986) presents one of the most compelling theoretical argumentations. Yet, the empirical support for their theory has been relatively weak, and an academic agreement is still lacking about the long-term consequences of technological innovation for the demographic composition of industries. This paper uses the information collected on 1,906 manufacturers during the period 1895 and 1993, to investigate the influence of technological innovation on the evolution of four different organizational populations - i.e. Great Britain, Germany, France and Italy. The findings of this research only partially agree with the theory. Our results show that, while innovations promoted entries, incumbent firms survived to environmental changes. The implications of this work are related to the literatures of strategic management and population ecology.

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1. Introduction

Technological innovation has been widely seen as one of the determinants of environmental selection. The literature on this topic provides compelling evidence on how technological progress shapes the development of industries (e.g. Tushman and Anderson 1986; Henderson and Clark, 1990; Tushman and Rosenkopf, 1992; Anderson and Tushman, 2001). In a similar vein, ecologists look at the variety of organizational forms as the byproduct of the rise and fall of different organizational groups in response to environmental discontinuities and they acknowledge technological innovation as one of them (e.g. Hannan and Freeman, 1989; Anderson, 1995).

The findings of this literature suggest that new entrants tend to outperform incumbents, especially when innovations are not purely incremental - e.g. Tushman and Anderson (1986). Following this line of reasoning, new entrants are more likely to succeed because they have a greater incentive to invest in radical innovations (Henderson, 1993), and are less likely to be burdened with their existing routines and competencies (Levitt and March, 1988). Nevertheless, empirical evidence suggests that, in the long-term, incumbents are more likely to survive, even in presence of innovations brought about by new entrants (Klepper, 1996; Klepper and Simons, 2000).

Thus, although the literature on innovation provides an interesting theoretical framework to approach the problem, the empirical support for its arguments has been relatively weak, and an academic agreement is still lacking about the long-term consequences of technological innovations for the demographic composition of organizational populations. This study advances this line of inquiry, exploring the influence of technological innovations on industrial development.

To reach this goal, the article will be organized according to the following outline. The next section will deepen the motivations of the study and its theoretical aspects. Then, the following will introduce the empirical setting of the work and will describe the technological evolution of the motorcycle, object of our analysis. The research question will then be explored studying the vital rates of 1,906 motorcycle

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producers operating in the four most important European industries – i.e. the Great Britain, France, Germany and Italy – during the period included between 1885 and 1993. Finally, the last two sections of the paper will introduce the results, and their theoretical implications.

2. Theory

After studying 46 different products, Gort and Klepper (1982) advanced a theory of industrial evolution marked by five stages: after an initial phase (i), several new entries take place (ii), leading the to the attainment of the peak of density of producers (iii). Then, the number of firms diminishes (iv), until a level of stability is reached (v). Among the several explanations advanced for understanding this often-observed evolutionary pattern, technological innovation occupies a prominent role. To be right, the literature assumes two conflicting perspectives on this topic. *On the one hand*, several authors are currently sustaining the incremental nature of technological evolution (e.g. Adner and Levinthal, 2000; Basalla, 1988). Basalla, for instance, remarks that the emphasis on the discontinuity of technologies represents the consequence of an ignorance of the antecedents, because "any new thing that appears in the made world is based on some object already in existence" (1988, p. 45). In general, the continuity implicit in technological evolution tend to be obscured by either to over-emphasize its departure from the past, or to equate technological innovation with its effects. On the contrary, by keeping technical development and market application distinct, what at first glance looks like a radical improvement, may stem from the application of the existing technological knowledge to a different domain (Adner and Levinthal, 2000). Therefore, even when a new technology emerges as a result of facing a new selection environment, the continuity underlying this process cannot be ignored. Evidences in support of this perspective were offered by the studies of Jeffrey (1995) in the heart pacemakers' production, and by Landau and Rosenberg (1991) in chemistry among the others.

On the other hand, several evidences support the discontinuous nature of technological change (e.g. Tushman and Anderson, 1986; Anderson, and Tushman, 1990). Abernathy (1978), for instance, proposed a life cycle theory of industrial evolution characterized by three macro phases. Industries typically begin in a fluid phase, characterized by a high degree of uncertainty in product functionality. During the first phase, innovation is more likely to be radical. As the features of the product stabilize, the industry first moves into a transitional phase, and then into a specific phase. As time passes, competition becomes focused on reducing cost and production facilities oriented to efficiency, in order to exploit economies of scale. According to this model, the establishment of a dominant design[i] represents the key event responsible for the transition from a fluid to a specific phase. Along a similar reasoning, Tushman and Rosenkopf (1992) maintained that the core technology of an industry evolves through a model of punctual equilibrium. A discontinuous innovation inaugurates the technological cycle, leading to an era of ferment, during which the new technology replaces the previous one. In a short period of time, several incremental improvements of the new technology emerge, beginning to compete with each other, until one of them is selected by the environment to become the dominant design. Then, the industry progressively consolidates its production around few producers, unless a new innovation rejuvenates it, and the evolutionary cycle may restart (Abernathy and Clark, 1986). Podolny and Stuart (1995), Rosenkopf and Tushman (1998) among others, offered support to this theory.

Clearly, the distance between these two interpretations – i.e. gradual *versus* punctual - is related to a different perspective on the nature of technological changes, as well as to the ability of organizations to adapt to them. Tushman and Anderson (1986) provided a useful categorization to interpret the interplay between environmental change and organizational survival. They classified innovations in two general types, named competence-destroying and competence-enhancing innovations. A competence-destroying innovation creates a new class of products - e.g. automobiles -, or replaces the previous one - e.g. diesel *versus* steam engines. The introduction of a similar innovation is supposed to make obsolete the existing knowledge, and it is usually associated to important changes in the power structure of the industry. For these reasons, “competence destroying discontinuities will be associated with increased entry-to-exit ratios and an increase in interfirm sales variability” (Tushman and Anderson, 1986, p. 446). On the contrary, competence-enhancing innovations represent incremental improvements either in the price-quality ratio, or in the performance of existing products. Similar innovations replace the old technique, but without nullifying the existing knowledge. Incumbent organizations are more prone to develop them and, therefore, the competitive landscape of an industry is supposed to consolidate in consequence of their introduction: competence-enhancing discontinuities "will be reflected in relatively fewer entries to exits and a decrease in interfirm sales variability" (1986, p. 445). In a longitudinal study of the concrete industry, Anderson and Tushman (1990) identified two innovations of the type enhancing, and three destroying during the 90 years of its history. Similarly, in the glass industry, in a span of time included between 1900 and 1960, they have found the presence of one innovation of type enhancing, and three destroying. Finally, one incremental innovation and two radicals marked the evolution of the minicomputer industry during the period included between 1958 and 1982. The hypotheses advanced about the demographic consequences of such changes – i.e. dominance of new entries in presence of radical innovations, whereas the opposite in case of incremental changes – found support only for the enhancing innovations.

Refining the model proposed by Tushman and Anderson (1986), Henderson and Clark (1990) tried to improve their dichotomy between incremental and radical innovations. According to these authors, along these two categories, another type of innovation marks the evolution of products, namely that defined as architectural – i.e. the innovation that modifies the relationship among the different parts of a product. As a result of a similar progress, some organizational competencies may easily be deployed to the new technology, but others become obsolete. They provided evidence on this claim studying the development of the jet engine technology, remarking that it "initially appeared to have important but straightforward implications for the airframe technology. Established firms in the industry understood that they would need to develop jet engine expertise, but failed to understand the ways in which its introduction would change the interactions between the engine and the rest of the plane in complex and subtle ways" (1990, p. 17). In a similar vein, their empirical analysis of the photolithography industry between 1987 and 1988 confirmed the difficulties of firms to cope with similar changes. Since most of the information potentially helping organizations to de-codify such innovations is hidden by the routinezed learning procedures, incumbent organizations are less efficient than new entrants in developing architectural innovations and, thus, more prone to fail in presence of them (Henderson and Clark, 1990).

A similar reasoning is also consistent with an inertial perspective of organizations (Hannan and Freeman, 1984). Organizational ecology in fact provided extensive evidence that modifying the technological core of a firm increases its risks of failure (e.g. Barnett, 1990). In particular, this hazard turns out to be proportional to the size and age of the firm (Carroll and Teo, 1996). Moreover, organizational inertia stems also from the incremental nature of learning, which is molded by routines that gradually change in time, depending on how the performance conforms to predefined expectations (Levitt and March, 1988). Incumbent firms, therefore, not only are less prone to recognize technological changes, but they also face more problems in implementing it, comparatively to new entrants. New entrants in fact have a greater incentive to invest in radical innovation (Henderson, 1993), or not be burdened with their existing resources, routines or competencies (Aldrich, 1999).

To summarize this theoretical section, technological innovation is currently considered as one of the most important variables shaping industrial evolution. Yet, while the literature on innovation provides an interesting theoretical framework to approach the interplay between technological innovation and industrial evolution, the empirical support for its arguments has been relatively weak, and an academic agreement is still lacking about the long-term consequences of technological innovations for the demographic composition of organizational populations (Klepper and Simons, 1999). Therefore, building on this line of inquiry, the present work will explore the evolutionary trajectories of the European motorcycle industry, investigating the influence of technological innovation on the processes of demographical turnover of four organizational populations - i.e. the Great Britain, Germany, France and Italy. We selected these four countries because the diversity of their industrial history, and the considerable heterogeneity of the evolutionary trajectories followed by the local organizational populations greatly facilitate a comparative approach. Furthermore, we believe that the motorcycle industry represents an ideal empirical setting to investigate a similar research question: the ferment preceding the definition of the industrial dominant design, product's, process's and complementary assets' innovations allow us to investigate different facets of the interplay among technological evolution, industry development and organizational survival.

3. Technological innovations in the motorcycle industry

3.1 Data

In choosing the populations for this research, we opted for the European motorcycle industry for three main reasons. First, the nature of this industry, global but at the same time nationally heterogeneous represents an ideal field to explore the present research question. Second, the accurate records of vital events allowed us to avoid problems related to left truncation and to study the effects of density on the organizational vital rates over the complete history of the population. Last, the significant body of research on the ecological dynamics of automobile organizations (Torres, 1995; Hannan et al., 1995; Hannan, 1997; Hannan et al., 1998; Dobrev, Kim and Hannan, 2001) greatly facilitates comparison and accumulation of empirical results.

The data used in this study include 1,906 motorcycle producers operating in the United Kingdom, German, Italian and French motorcycle industry during the period included between 1885 and 1993. The main source of information comes from the book "The Complete Illustrate Encyclopedia of the World's Motorcycles" (Tragatsch, 1977; 2000) considered the most reliable text for this industry, and from the "Enciclopedia della Motocicletta" (Wilson, 1996) that includes the date of birth and disbanding of each firm in these countries. The year in which the first model appears in these books was considered as the year of birth of a firm, whereas the year in which the last model disappears from the register was coded as the firm's death. Information were refined using the register of motorcycle production that contains a description of most of the models patented in the United Kingdom (Hume, 1991), as well as "British Motorcycles since 1900" (Collins, 1998). In order to prove the reliability of the data, we consulted the magazines of the period: *Motor Age* (from

1899), *Cycle Trade Journal* (from 1897), and *Motor* (from 1903). Finally, we crosschecked all the information using other references: "A-Z of Motorcycle" (Brown, 1997), "Historic Motorcycles" (Burgess Wise, 1973), "The Ultimate Motorcycle Book" (Wilson, 1993), and "Encyclopedia of Motorcycling" (Bishop and Barrington, 1995) confirmed the reliability of the data presented.

3.2 The technological trajectory of the product

A motorcycle incorporates many unique components into an intricate and an effective whole. The components of a motorcycle can be separated into five main systems: engine, transmission, wheel, structural, and control. The engine system transforms chemical energy (i.e. gasoline) into mechanical power. This system includes the fuel storage and delivery, intake, exhaust, ignition, combustion chamber, and cooling subsystems. The transmission system transfers power from the engine to the wheels. This includes the clutch, gearbox, and both the primary and final drives. The wheel system transfers mechanical power from the transmission into a force against the road surface. The wheel system includes the wheels, the tires and the brakes. The tires transmit the wheels' force to the road surface. The brakes interrupt the transfer of transmission to the road. The structural system holds everything together; it maintains the proper relation between components, and supports the rider. This system includes the chassis, the suspension and the seat. The control system allows the operator to activate the motorcycle and to adjust some vehicle parameter in the desired direction. The control system includes the starter, clutch lever, gear-shift, brake levers, throttle control, and steering. Let's now briefly introduce the main events that shaped the technological evolution of each of these five components.

The *structural system* evolved through several changes. The first changes took place during the first years of the industry and they were related to the lack of dominant design for the engine, for the position of the rider, and for the tank. The Werner brothers - in 1897 in France - were the first to eliminate the third wheel used by Bouton few years before, and to place the seat of the pilot over the rear wheel fork (Tragatsch, 1977). After several experimentations, the rider first - in England at the end of the Nineteenth/beginning of the Twentieth century -, and the tank few years later, found the modern position in the chassis. Important changes involved the suspensions at the beginning of the 1900's. While Peugeot, in 1904, became the first producer to offer a ‘real’ rear suspension, the innovation quickly disseminates throughout the Continent (Wilson, 1996). Since then, its progress proceeded slowly until the Forties, with the sole exceptions of the triangle suspension introduced by Vincent in 1928, and of the rear-plunger suspension introduced by BMW in 1938. An important evolutionary step took place in 1949 in Germany, when Imme proposed the cantilevered swing-arm rear suspension (Wilson, 1993). Beyond the technical implications of this innovation, both the lightness and the aesthetics of the motorcycle were significantly improved. Furthermore, during the early Twenties, producers began to replace druid forks with spring forks. By the mid 1930s, the latter became the industry standard. At least until 1935, year in which BMW introduced the front telescopic fork (Burgess Wise, 1973). This innovation assumed particular importance because of the remarkable improvement it boosted to the maneuverability of motorcycles in off-road. The telescopic fork consists of two separate, concentric tubes whose relative movement is regulated by a shock. The inner tube mounts to the chassis, and slides within the outer tube that is mounted the wheel hub. With a few refinements – e.g. anti-dive damping -, the telescopic fork still today represents the industry standard.

The *wheel system* has also seen great improvements, with maybe the greatest occurring in 1888, when John Dunlop invented the pneumatic tire, which improved the traction of motorcycles and provided them with some suspension. In regard to the brake component, although at the beginning motorcycles offered hand-operated brakes that controlled the driving wheel, a brake for each wheel became soon the norm. An important improvement for the brake came in 1914 with the introduction of the dummy-rim[ii], which became almost immediately a standard in several European countries (Tragatsch, 1977). In the late 1960s, disc brakes were introduced: they consistently improved the braking performance over the range of speeds and simplified maintenance.

Naturally the *engine system* has greatly changed since 1885. The most important improvement relates to the definition of its standard positioning within the chassis. This configuration still today confers to the motorcycle its characteristic aspect. The step took place in the main European countries between 1902 and the 1903 (Tragatsch, 1977). Up to that time, every possible engine position was attempted: on the handle bar - Werner in 1899 in France -, on the front hub - Singer in Germany -, close to the pedals - Hildebrand and Wolfmüller -, back to the pedals - Beeston in Great Britain -, back of the seat – Ormonde in the UK -, or even hauled, as in Italy (Tragatsch, 2000). Regarding the distribution, rotary valves, driven by chain from the crankshaft, gradually replaced the poppet valves. Moreover, the desire for increased speed and efficiency prompted the development of the overhead camshaft system. To offer the reader an idea of the importance of this progress, today most motorcycles use double overhead camshafts to operate inlet and exhaust valves. The progress took place in 1914, thanks particularly to the impulse of Peugeot, which publicly demonstrated the superiority of this solution (Tragatsch, 1977). On the contrary, regarding to the configuration of the cylinders, a univocal solution was never reached. By the 1920s, most motorcycles had two cylinder engines, although one-cylinder engines were used, and four cylinder engines had already made a strong showing. Similarly, the layout of cylinders never settled to one standard setting. The "V" configuration became very popular as it seemed to fit so well into the diamond frame and provided some balance; even this configuration, however, had its varieties: the 45 degree, 90 degree, and the "L" derivative. Vertical, horizontal, transverse, and opposing layouts were also adopted. BMW introduced its classic "Boxer" engine in 1923 (Wilson, 1996). Today most motorcycles have either 2 or 4 cylinders, but their layout greatly varies: vertical, horizontal and cross-sectional solutions anchor can still be found on motorcycles.

The *transmission system* knew its main progresses with the introduction of the clutch, and of the chain transmission. Until 1905 nearly no motorcycle was equipped of clutch, or of a gearbox, and the first motorcycles used physical push to drive the crankshaft, starting the engine. Pedalling represented the common way to start the engine, and stopping was the best solution to switch it off: it was very difficult, therefore, to maintain the engine on. A more sophisticated solution was to adopt mobile pulleys to modify the friction of the transmission belt to stop or to move

(Burgess Wise, 1973). The diffusion of clutches, around to 1906, was particularly important since it allowed to stop and to depart easily. Similarly, since 1905, belt systems represented the most common way to transmitting mechanical power into a force against the road surface. Yet, riders soon realized how time-consuming and costly was to replace a similar solution. While chains were proven to be more durable, several producers – mainly the English – were reluctant to adopting them, mostly because they needed a more technologically sophisticated clutch, as well as a 'real' gearbox. Since in the early years of the 1900s the level of the competition was high, not many producers were oriented to invest in developing complex clutch-gearbox systems. Therefore, the big players were the first to introduce this transmission in 1907/1908 (Tragatsch, 1977). The benefits of this solution went beyond the technical improvement: chain systems not only provided look and styling to motorcycles, but also enhanced the feeling of reliability of products. Today's motorcycles continue to use the belt and chain shaft drive methods, but chain drive remains the most prevalent.

Finally, with the sole exception of the starter, motorcycle *controls* have remained essentially unchanged since the 1920s. As we said before, by the 1900, pedals were the common method of starting the motorcycle's engine. Looking for easier and faster ways to get going, Alfred Scott introduced the kickstart in 1909, which became an industry standard in only two years (Burgess Wise, 1973). Then, the next major innovation regarded the introduction of the electric starter, which, to be right, did not get momentum since the early Sixties, when Honda proposed it on some of its 1965's models.

Table 1 synthesizes the dates of introduction of the most relevant technological improvements in this industry with a short description of their relative importance.

Insert Table 1 about here

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4. The evolution of the European motorcycle industry, 1885-1993

The origins of the motorcycle industry can be traced back to 1885. In that year, Gottlieb Daimler created the very first motorcycle in the world (Bishop and Barrington, 1995). To be right, it was just a prototype and he soon abandoned it. Thus, Hildebrand and Wolfmuller of Munich can be considered the first real manufacturer. However, their experiment was not that much successful. Much better was the success obtained by Colonel Holden in England, and Count De Dion in France (in partnership with Bouton), who, at the end of the Ninetieth century, inaugurated their national industries. In 1897, De Dion offered his engine for general sale, enabling scores of experimenters to copy and to improve upon. He obtained an outstanding penetration of the market and became the most important engine manufacturers. Needless to say, he soon had many rivals, of which the Belgian Minerva and the French Clement were the most popular (Tragatsch, 1977).

The definition of a standard position for the engine facilitated the spread of motorcycles' production in several European countries. In the meantime, social events, like exhibitions and competitions, helped manufacturers to prove the reliability and quality of their products. In 1903, in London, the first important exhibition, "The Stanley National Show", took place and in the same year, the Autocycle Club, opened to all motorized vehicle, was born in England. In 1904, the Motorcycle Club de France and the Fédération Internationale des Clubs Motocyclistes were founded. The first recorded national race was held in 1897 at Richmond (Great Britain), whilst the first international competition took place in 1904 in France, namely the International Coupé Race (Bishop and Barrington, 1995). The Tourist Trophy, one of the most important world's races, took place for the first time in 1907 at the Isle of Man, off the West Coast of England.

The positive economic climate of those years promoted the growth of national industries throughout Europe. In 1904, new registrations reached 21,974 motorcycles in the UK and 19,886 in France, reaching the same number of cars (Tragatsch, 1977). Italy and Germany, while slowly growing, were steps behind these two leading countries: the first motorcycle club, for instance, in Italy was founded only in 1911.

The arrival of the Great War consolidated the emerged landscape. Seeing the possibility of extra-sales, Scott and Triumph in United Kingdom, NSU in Germany, FN in Belgium vied in fact each other for the lucrative Government orders (Collins, 1998).

During the years immediately following WWI, Germany and France saw an upsurge of interest in motorcycling. The golden age of motorcycle saw the light: and a number of imaginative and advanced designs were produced (Wilson, 1996). After 1919 the growth was quite high, in all the European countries. By the early 1920s Great Britain was the world undisputed volume producer and the biggest exporter. In 1925, out of 120,000 motorcycles produced, 48,121 were exported. In 1927, a reporter of the *Daily Telegraph* wrote:

> "It is depressing to the motorists traveling on the Continent to meet so rarely a British-made motor-car, but everywhere the British motor-cycles is upon the roads, and the foreigner willingly concedes its superiority. In design, lightness and efficiency it beats everything."

Yet, between 1929 and 1934 things changed, and the home and export market in Great Britain suffered a massive flop: the overall production dropped from 147,000 to 58,500 units, and the exports collapsed to 16,807 (Koerner, 1995, p. 57). Two main reasons favored the decline of the British industry. Firstly, motorcycles remained technologically stagnant, in comparison with the progress of the motor-car industry, where electric-starters, all metal bodies for better weather protection, as well as significant safety improvements were introduced. The lack of technical progress of the United Kingdom motorcycle industry was indeed compared with products more advanced coming, for instance, from Germany and Italy. Secondly, in France and Germany, the Government reduced or simply removed the tax and regulations for motorcycles under 200cc. engine capacity. On the contrary, the SMMT – the Society of Motor Manufacturers and Traders – was unable to persuade its members to reach a unified position on taxation, despite the repeated invitations from the government to do so (Koerner, 1995). The net result was that during the late 1930s the German industry became the first European producer and the biggest exporter – 1937: 31,307 exports for Germany and 25,350 for the UK.

In general, the years after WWII favored a renewal of enthusiasm around the motorcycle production. The demand of motorbikes increased rapidly in every European Country. Smith (1981) calculated that in the period included between 1953 and 1975, the European production of motorcycles increased of five times. Nevertheless, the market became progressively polarized "into stylishly dressed scooter and leather-clad racers who rode and lived for their bikes" (Tragatsch, 2000, p. 48). The change in the environment favored those countries more experienced in producing small-capacity motorcycles. Japanese manufacturers gained momentum, and their exports became soon very high in Great Britain. In France and Italy, on the contrary, governmental restrictions helped partially to protect the national markets. During the same period, United Kingdom and Germany, uncomfortable with the way motorcycling appeared to be going, fell behind Italy that gained the best position in the market. Production in Great Britain fell from 154,000 – historical peak - in 1953, to 70,000 in 1970. Similarly, the production in Germany declined from 576,000 motorcycles in 1953, to 285,000 in 1975. During those years, Italy emerged as the first European producer – 821,000 motorcycles in 1975 -, and exporter (Smith, 1981).

The impressive acceleration of foreign trade during the 1960's and 1970's, due to the abolishment of tariffs between the members of the EU, favored the development of an international market for motorcycles. Today, Italy represents by far the most important European market, the best net exporter, whereas the United Kingdom and France industries significantly declined. The evolution of Germany was quite different. After the decline of the Seventies, the production gained momentum again, and it now represents the second European exporter, and the second market for employees - 1994: 17,883 in Italy, 12,357 in Germany (OECD, 2000) - and motorcycles registrations - Italy 1998: 922,743 in Italy, 417,746 in Germany, 362,039 in France and 120,411 in the UK (ACEM, 2000). In general, to provide the reader with the climate in 1995, Italians bought half of all the mopeds sold in Europe, while in the motorcycles segment, purchases were highest in Germany, which accounted for 40% of all the motorcycles sales in Europe (ACEM, 2000).

Insert Figure 1 to 4 about here

Figures from 1 to 4 present the pattern of density and entries of our sample. The first consideration emerging from the analysis of these diagrams is that not all the evolutionary trajectories look consistent with the pattern advanced by Gort and Klepper (1982). Italy, in particular, not even today seems to resemble the typical characteristics of a mature industry - i.e. the reduction of the number of producers and its natural consolidation. Second, observing figures 1 to 4 we evince that the waves of entries took place almost contemporaneously in these Countries. Although with different intensity in different nations, these populations experienced similar gales of entries during the years included between 1895 and 1900, about 1908, 1919, 1946, as well as in the second part of the Sixties. In a similar vein, an analysis of Table 1 suggests that the development of motorcycles was significantly improved during the first years of the last Century, as well as in 1949 and 1965. A similar claim is also supported looking at the years of publication of the "Manuale Hoepli del Motociclista", issued in 1903, 1909 and 1915, since this publication had to be updated at the time in which the old edition was considered obsolete for the technology of the period.

Did technological innovation influence the evolutionary trajectories of these populations? A comparison between the years of the entry's waves and the relevant dates of technological innovation reveals the matching suggested by the theory. The years preceding the definition of the dominant design of the product - i.e. about 1903 – were marked by the entrepreneurial ferment proposed by Abernathy (1978) and Tushman and Rosenkopf (1992). Similarly 1908, with the diffusion of the chain-transmission method, represented a year of increasing entries, particularly in the Great Britain. The incremental innovations of the years before the First World War insignificantly have influenced the vital rates the analyzed populations. Contrarily to the expectations, the evolution of suspensions did not boost new entries. Finally, the Japanese-era seems to have heterogeneously affected European populations: during those years Italy in particular, but also France, experienced new entries.

Nevertheless, a similar outline offers only a partial representation of the problem. Changes in the architecture of the product, competence destroying and niches' opening innovations, are also supposed to promote demographical turnover into populations, or as Schumpeter (1934) would say, to favor gales of creative destruction. Anderson and Tushman in fact remarked "eras of ferment, in contrast to eras of incremental change, are associated with significantly increased uncertainty" and that "uncertainty is the environmental dimension that most strongly influences industry exit rates" (2001, pp. 700-701). Similarly, both Tushman and Anderson (1986) and Henderson and Clark (1990), suggested that competence-destroying changes favor entries and increase incumbents' exits, contributing to alter the demographical characteristics of an industry.

Figures 5 to 8 help to explore the robustness of these claims. These plots report the yearly oscillations of the average ages of manufacturers in each of the four populations analyzed. The advantage of this representation, in comparison both to the analysis of entries and to density, is to disaggregate the number of organizations in an indicator representing the degree of demographical turnover induced by technological discontinuities. A similar variable not only allow us to trace out the waves of new entries, but also sheds light on the medium-long term survival chances of incumbent firms in presence of environmental shifts. The fluctuations of the average ages of the various populations in 1903, 1919 and 1946 are associated to the abovementioned entrepreneurial ferment.

Insert Figure 5-8 about here

Observing these diagrams is it possible to argue two general considerations. Contrarily to what expected, the architectural innovations of 1903, 1908, and 1935 did not promote demographical turnovers. In the years following these dates the average age of incumbent firms increases almost exponentially, suggesting that in the medium-long term, incumbents rather than new entrants, survived to technological innovations. The consequences induced by the entry of the Japanese producers deserve a different consideration. This event marked the evolution of Great Britain (Figure 5) and France (Figure 8). The competitiveness of the Japanese producers for the former, and new entries for the latter contributed to modify the evolutionary trajectories of these populations. On the contrary, the opposite happened in Germany (Figure 6) and in Italy (Figure 7). For these populations, the years following the two World Wars, clearly promoted an upsurge of entries. Nonetheless, technological innovation did not significantly affect the evolution of these populations.[iii]

5. Discussion and Conclusions

In 1986, Tushman and Anderson concluded their paper suggesting "future research could also explore the linkage between technological evolution and population phenomena, such as structural evolution, mortality rate, or strategic groups, as well as organizational phenomena, such as adaptation, succession and political processes" (p. 463). In this study we have tried to deepen some of these issues, proposing a new perspective to investigate the interplay between technological innovations and industrial evolution. To support the robustness of our conclusions we focused on a comparative study, first analyzing the technological development of motorcycles, and then, matching it with the evolutionary trajectories of 1,906 producers in Great Britain, France, Germany and Italy, during the period included between 1885 and 1993.

The findings obtained only partially agree with previous studies. According with the theoretical reasoning of Tushman and Anderson, (1986) and of Tushman and Rosenkopf (1992), among the others, we found main technological improvements to increase organizational entries. Nonetheless, we provided evidence that the latter did not significantly affect the demography of the populations analyzed. Last, the entry of the Japanese producers profoundly influenced the evolutionary trajectory of the British and of the French populations, but only marginally that of German and Italian producers.

We believe that the implications of this study are threefold. First, an important contribution of this work is clearly related to the literature on technological change and industrial shakeouts. As Klepper and Simmons (1999) noted, theories on industrial shakeouts can be classified into two groups. On the one hand, 'event theories' consider shakeouts to be triggered by specific technological events. Utterback and Suarez (1993), for instance, underlined the emergence of a dominant design as responsible for industrial shakeouts. With the introduction of a dominant design, consumer demand shifts to the standard products and firms begin competing to produce them at the lowest cost. Since exits increase because of the competition, and entries decrease because the profit opportunities diminish, industrial shakeout emerges as the byproduct of this process. On the other hand, 'competitive advantage theories' consider competitive forces to be responsible for industrial trajectories. Klepper (1996), for instance, developed a model in which increasing returns to R&D and convex costs of growth cause the leading firms of a market to develop a competitive advantage over others, through their superior investments in innovation. Since entries become unprofitable, and leading firms continue to force out the less able firms, the market converge to a highly concentrated oligopoly that displays scarce product innovation. Following this evolutionary view of industrial development, fast movers enjoy a durable competitive advantage over late entrants. The findings of this paper exclude an 'event perspective' of industrial shakeouts. Yet, our descriptive analysis cannot clearly untangle the origins of industrial shakeouts. An evolutionary perspective, as well as a density dependence theory (Hannan, 1986) of industrial development, for instance, can equally account for the trajectories observed. More effort is needed to clarify this issue.

Second, research on technological innovation repeatedly emphasized that technological innovation evolve punctually. Our study does not support these conclusions. Recent works have demonstrated that discontinuous technological changes are rare (e.g. Mokyr, 1990). Levinthal (1998), for instance, stated that the increasing attention of the literature on punctual technological changes represents the result of an over-emphasis on the commercial implications of innovations. Similarly, Basalla (1988) contrasted the conclusions on the discontinuous nature of technological innovation, because of their general ignorance of the antecedents. While the debate still remains open, the notion of speciation has been recently introduced to integrate these perspectives. This concept has been used to lay out the theoretical foundations underpinning an incremental view of technological change at the industry level (Levinthal, 1998). According to this perspective, environmental discontinuities would not happen as a result of single events. On the contrary, similarly to biology, the realization of punctual events would be determined by speciation processes, namely through the application of the existing technological knowledge to new domains of application. Therefore, this literature suggests, firms proactively seeking new challenges to their current capabilities are more likely to increase breadth of their knowledge base and to transform environmental shifts into incremental steps (Cattani, 2001). The results of this study open interesting perspective for research on organizational adaptation.

Third, the ability of an organization to adapt to environmental changes critically depends on the characteristics of the population of which firm belongs to. The strategy of by Japanese producers, promoting low costs and quality (Pascale, 1984), implied a radical shift for many organizations of this industry. As the descriptive analysis of this work has illustrated the Japanese development positively influenced the evolution of the Italian population. The opposite happened to the English industry. Why do the Italian firms benefited of the entry of Japanese manufacturers, while the English suffered from it? Since the work of Cohen and Levinthal (1990) we know that the ability of a firm to exploit external knowledge and apply it to commercial ends is defined as its absorptive capacity. We believe that this concept, usually applied to individual firms, can be extended to shed light on the competitive dynamics experienced by different populations. Miner (1995) developed a similar construct observing a “systematic change in the nature and mix of routines in a population of organizations, arising from experience” (1995, p. 116). The results of this work seem to suggest the presence of different absorptive capacities between the Italian and the English populations. We believe that this line of research might be promising to improve our comprehension of the relationship linking technological innovation to industrial evolution.

It would be unfair not to recognize that this work suffers from at least four main limitations. The first relates to the methodology of this work. Since we believe competence-destroying innovations to be natural population-level processes, we chose to analyze the evolution of the average ages of the four populations selected. Yet, the lack of quantitative analyses partially constrains the power of our inferences. The second limitation relates to the low level of endogenous innovations observed in the motorcycle industry. Thus, the findings of this work may be partly idiosyncratic to the populations observed: the analysis of technological-intensive empirical settings – e.g. the aircraft or the pharmaceutical industry - may produce different results. The third limit concerns the delineation of political and social units under study. According to other studies (Hannan et al., 1995) we decided to operate the selection at national level. Yet, sovra-national processes – e.g. mergers and acquisitions - clearly have contaminated the dynamics of local competition. Last, no information on organizational size is available to control for the effects of possible heterogeneous effects that organizations are likely to have on the vital rates (e.g. Barnett, 1997).

Different and more fine-grained data are needed to address the limitations of this research and to substantially advance it. However imperfect, we believe that this study provides new empirical evidence and interesting theoretical implications to improve our understanding of the interplay among technology, organizational demography and industrial evolution.

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Table 1. Main innovations in the European motorcycle industry, 1885-1993.*

Year	Event	Type of discontinuity	Importance
1888	Invention of pneumatic tire	Architectural	Improves safety and the grip of motorcycles
1903	Standard position for the engine	Architectural	The dominant design of the product is selected
1904	Introduction of rear suspensions	Competence enhancing	Improves the comfort
1906	Introduction of clutch	Competence enhancing	Allows easier (re)starts
1908	Chain transmission	Architectural	Requires a more sophisticated clutch, as well as more strength gear and frame
1909	Introduction of kick starter	Competence enhancing	Simplify ignition
1913	Introduction of overhead camshaft system	Competence enhancing	Improves the motorcycle's performance
1914	Introduction of 'dummy-rim' brakes	Competence enhancing	Improves the performance
1935	Telescopic front forks	Niche opening	Significantly improves off-road performance
1949	Cantilevered swing-arm rear suspensions	Competence enhancing	Simplifies the product and enhance its aesthetic
1960-1965	Beginning of the Japanese era Electric starter	Competence destroying Niche opening	High quality products for a low price Opens the doors to the women's segment of the market
1968	Introduction of disc brakes	Competence enhancing	Improves the performance, and simplifies maintenance

* Besides the sources indicated in the methodological section of this work, Wilson (1993), Brown (1996) and Burgess Wise (1973) were consulted to realize this table.

Figure 1. Births and Density of Motorcycle Producers in United Kingdom, 1885-1993

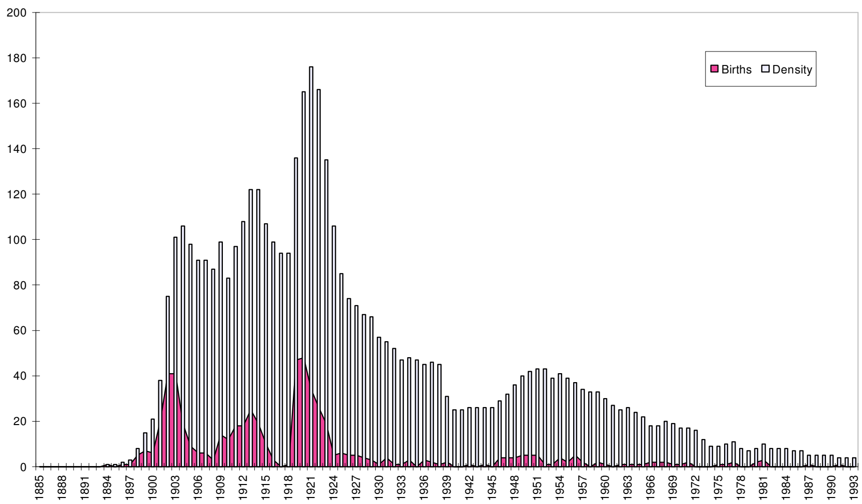


Figure 2. Births and Density of Motorcycle Producers in Germany, 1885-1993

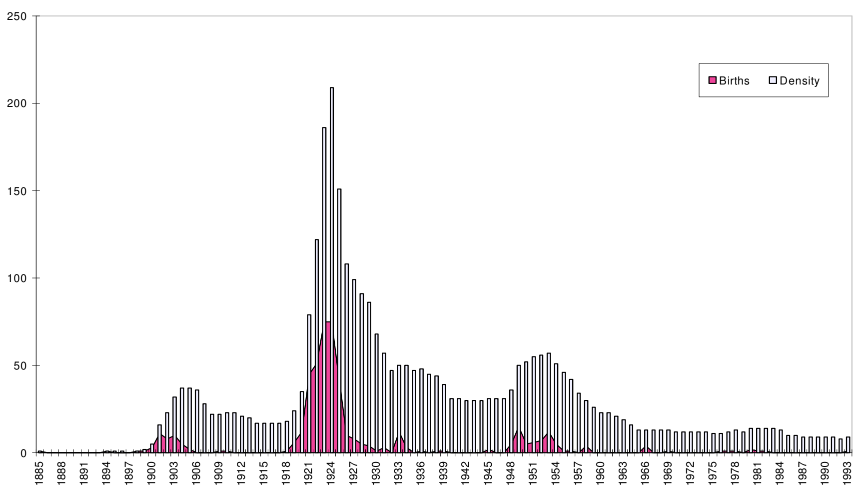


Figure 3. Births and Density of Motorcycle Producers in Italy, 1885-1993

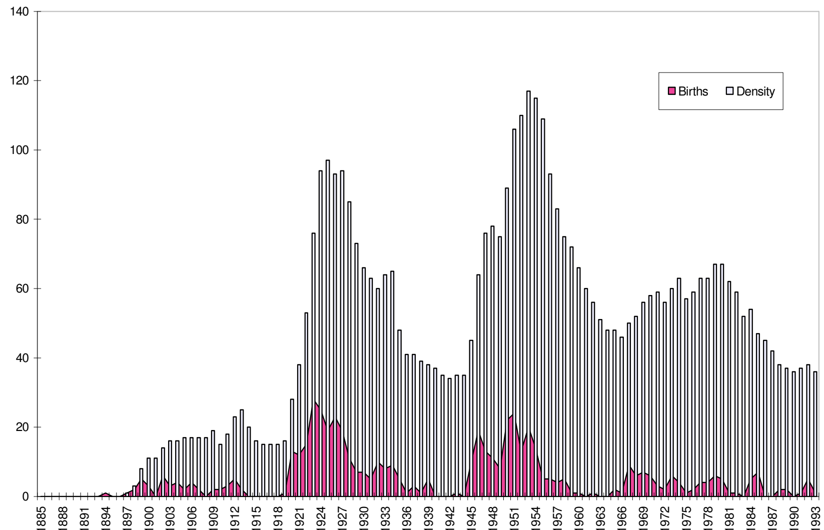


Figure 4. Births and Density of Motorcycle Producers in France, 1885-1993

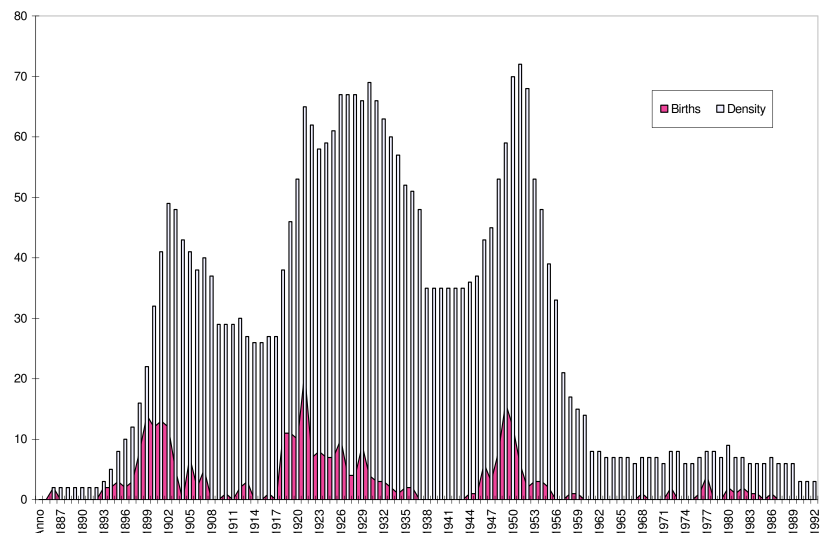


Figure 5. Average age of motorcycle producers in the United Kingdom, 1885-1993

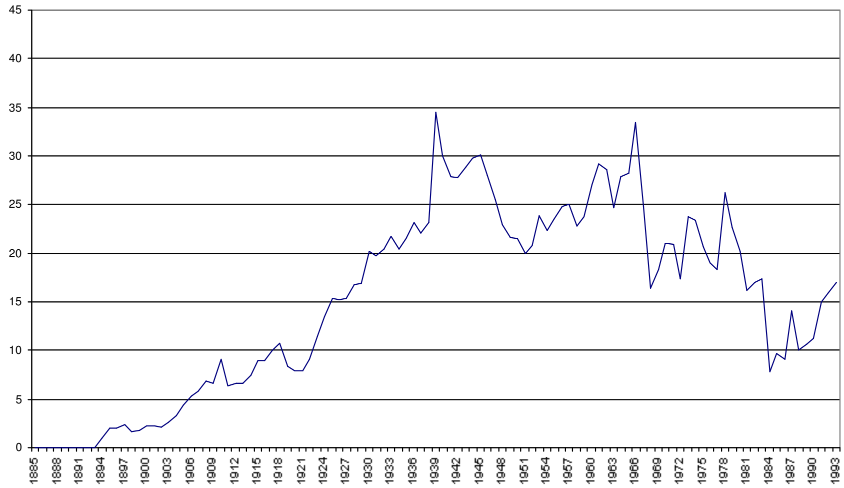


Figure 6. Average age of motorcycle producers in Germany, 1885-1993

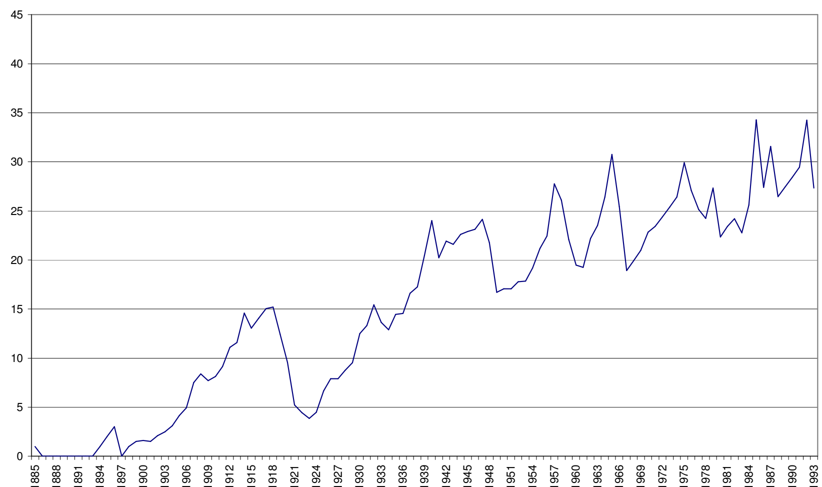


Figure 7. Average age of motorcycle producers in Italy, 1885-1993

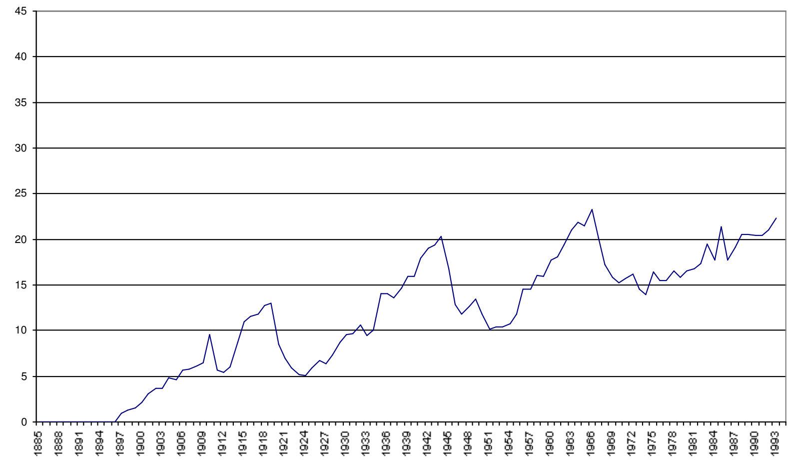
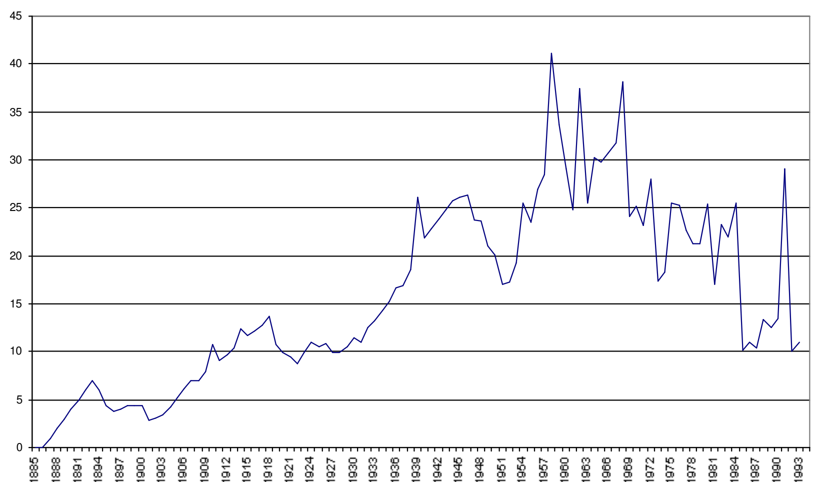


Figure 8. Average age of motorcycle producers in France, 1885-1993



Endnotes

[i] Suarez and Utterback, (1995) define a dominant design as a specific path, along an industry design hierarchy, which establishes dominance among competing design paths. Similarly, (Lee et al., 1995) consider a dominant design to be the distinctive way of providing a generic service or function that has maintained the highest level of market acceptance for a significant amount of time.

[ii] A similar brake relies upon a cantilevered fork to create friction against the dummy-rim, stopping the wheel.

[iii] As we said before, during the Seventies the Italian government adopted a protectionist strategy, but duties were applied only to the importation of motorcycles with capacities higher than 350cc.