textos de economia

INTERNAL COMBUSTION ENGINE LON RUN WAVE PATENTS: 1900 – 2019

Patentes de Motores à Combustão Interna: Uma Perspectiva de Longo Prazo, 1900-2019

Gilson Geraldino Silva Júnior
Doutor
Universidade Federal de Santa Catarina (UFSC)
Departamento de Economia e Relações Internacionais (DERI), Florianópolis, Brasil;
gilson.geraldino@ufsc.br
https://orcid.org/0000-0003-2361-9431

Marcelo Arend
Doutor
Universidade Federal de Santa Catarina (UFSC)
Departamento de Economia e Relações Internacionais (DERI), Florianópolis, Brasil;
marcelo.arend@ufsc.br
https://orcid.org/0000-0002-5748-9690

Thiago Rodrigues Lemos
Doutor
Universidade Federal de Santa Catarina (UFSC)
Departamento de Economia e Relações Internacionais (DERI), Florianópolis, Brasil;
thilemos@hotmail.com
https://orcid.org/0000-0001-9105-5151

A lista completa com informações dos autores está no final do artigo

ABSTRACT

Objetive: Internal Combust Engine (ICE) is a hot subject in this geo political moment, with green agenda under fire. Some people believe that electric mobility is the only option, but there is a long tradition and some options in combustion engines. In this paper we analyze ICE long run wave patents using Derwent Innovation database, part of Clarivate Analytics group. From 675 thousand records spread through 120 years we found deep swing positions: i) 1900's France (73%) and UK (22%) had 95% of ICE patents. In 1910's USA (20%) joint the club, and mutual with France (33%) and UK (40%) had 93% of total. In 1920's Germany alone had 77%, in 1930's and 1940's only USA had 73% and 70%, respectively. In 1950's USA (37,3%) and Germany (46,5%) had 84% of the total, and in 1960's Germany (50%) and UK (23%) had 73%. In 1970's and 1980's Japan was in the same position as Germany in 1920's with 74% and 76% share, respectively. In 1990's Japan (57%) and Germany (22%) had 79% of total, and in 2000's and 2010's China was the leader, but any country had more than 40% share, ii) from 1900's to 1950's the main companies were European and American, from 1960's to 1990's Japanese joined the club, and in 2000's and 2010's had similar mix. There are few papers about this article subject, particularly in a global and 120 years' perspective.
KEYWORDS: Internal combust engine. Long run waves. Patents

RESUMO

Objetivo: O Motor de Combustão Interno (Internal Combust Engine, ICE) é um assunto importante neste momento geopolítico, com a agenda verde sob ataque. Algumas pessoas acreditam que a mobilidade elétrica é a única opção, mas existe uma longa tradição de ICE muitas opções em motores à combustão. Neste artigo analisamos patentes ICE son a perspectiva de longo prazo usando o banco de dados Derwent Innovation, parte do grupo Clarivate Analytics. De 675 mil registros ao longo de 120 anos, encontramos mudanças substanciais: i) França (73%) e Reino Unido (22%) de 1900 detinham 95% das patentes ICE. Na década de 1910, os EUA (20%) aderiram ao clube, e junto com a França (33%) e o Reino Unido (40%) tiveram 93% do total. Na década de 1920, só a Alemanha tinha 77%, nas décadas de 1930 e 1940, apenas os EUA tinham 73% e 70%, respetivamente. Na década de 1950, os EUA (37,3%) e a Alemanha (46,5%) detinham 84% do total, e na década de 1960 a Alemanha (50%) e o Reino Unido (23%) tinham 73%. Nas décadas de 1970 e 1980, o Japão estava na mesma posição que a Alemanha na década de 1920, com 74% e 76% de participação, respectivamente. Na década de 1990, o Japão

(57%) e a Alemanha (22%) detinham 79% do total, e nas décadas de 2000 e 2010 a China era a líder, mas qualquer país tinha mais de 40% de participação, ii) de 1900 a 1950 as principais empresas eram europeias e americanas, de 1960 a 1990 os japoneses aderiram ao clube, e nos anos 2000 e 2010 havia mix semelhante. Existem poucos artigos sobre o tema deste artigo, particularmente numa perspectiva global e de 120 anos.

PALAVRAS-CHAVE: : Motor de combustão interna. Ondas de longo prazo. Patentes

Classificação JEL: N6, L62, 033,034

Recebido em: 25-02-2025 Aceito em: 11-06-2026

1 INTRODUCTION

There is a long debate about patents on one hand, long waves on the other, and a specific about long wave patents.

About patents, in 19/03/1474 the Venetian Senate passed by a large majority a patent act that regulated the granting of patents for novelty, ingenuity, and utility. The dominant view among patent law historians is that this act established an administrative-centered system, quite similar to the modern Anglo-American system. The impact of the act on patenting was substantial. The number of patents granted by the Venetian Senate grew considerably, increasing from five ad hoc privileges granted before 1474 to 43 patents approved between 1474 and 1500, 126 patents granted in 1501-1550, and 471 patents granted in 1551-1600. The interaction between patent law and guilds, associations of craftsmen and merchants played a key role in Medieval and Renaissance Europe (COMINO, GALASSO, GRAZIANO, 2020). But patents are not only the oldest and some of the widely appropriability mechanisms, but also an important source about inventions that could became an innovation. Schmookler is among the pioneers in use patents in economics of technology and wrote about the interpretation of patent statistics (1950), the utility of patent statistics (1953a), and patent application statistics as an index of inventive activity (1953b), whose contribution helped establish patent data analysis as a field of research.

However, there are lots of odds and even in use patents statistics, as Griliches (1990), Nicholas (2003) and Cohen et alli (2000) points out. In fact, patents and patent statistics have fascinated economists for a long time and helped draw answers to questions about sources of economic growth, the rate of technological change, the competitive position of different firms and countries, the dynamism of alternative industrial structures and arrangements all tend to revolve around notions of differential inventiveness. But not all inventions are patentable, not all inventions are patented, and the inventions that are patented differ greatly in "quality," in the magnitude of inventive output associated with them (GRILICHES, 1990). It is well known in the industrial organization literature that patents provide an imperfect measure of innovative output. It is commonly argued first, that not all significant technologies are

patented, and second, that most patents are trivial and have zero economic value, and there are industries where firms do not use patents as a primary mechanism to appropriate from R&D effort (as used to be the case in the semiconductor industry) (NICHOLAS, 2003). In addition to the prevention of copying, the most prominent motives for patenting include the prevention of rivals from patenting related inventions (i.e., patent blocking), the use of patents in negotiations and the prevention of suits. We find that firms commonly patent for different reasons in discrete product industries, such as chemicals, versus complex product industries, such as telecommunications equipment or semiconductors. In the former, firms appear to use their patents commonly to block the development of substitutes by rivals, and in the latter, firms are much more likely to use patents to force rivals into negotiations (COHEN et alli, 2000).

About long waves, Kondratieff is the pioneer with his analyses originally published in Germany in 1926, and translated to English in 1935 (Kondratieff, Stolper, 1935). According to him, there is reason to assume the existence of long waves of an average length of about 50 years in the capitalistic economy, but in the 1920's the investigation was difficult because of lack of data once there wasn't data before the end of the eighteenth century and even the data that he had were insufficient and not entirely trustable. He got data for USA, UK and France price index, 1700-1925, UK and France interest rate state bonds, 1815-1925, weekly wages of workers in the English cotton-textile industry, 1806-1910, and of English agricultural laborers ,1789-1910, the sum of French exports and imports, 1830-1910, consumption of coal in France, 1830-1915, production of coal, pig iron, and lead in England, 1840-1920 and give us the empirical characteristics and the nature of that long waves. Cars, patents, and car patents are out of Kondratieff charts.

Despite of internal combustion engine (ICE) ideas back to the 1680's, patents appear later, in the 1860's. Otto patent grant was in 1867, Diesel in 1892, Daimler in 1887, and Benz in 1886. ICE patent boom comes far later, in 1910's, and empirical economic studies about patents long waves back to 1930's, as Merton (1935) analysis about fluctuations in the rate of industrial invention in many fields as cotton machinery, weaving machinery, spinning machinery, telegraphy, telephony, 1846-1930, and automobile, aeroplane, radio, 1896-1930, show us. About automobile patents particularly, there were 40 in 1900, 720 in 1918, 121 in 1930. These ups and downs

in patent registers motivated Stafford (1952) asks: Is the rate of invention declining? He tried to answer it in a long run perspective, and used USA patent data from 1830's to the 1950's and concluded that "an outstanding trend for patented invention is its recent downward trend, the first in the history of our patent system. The growth curve of patent applications since 1840 corresponds closely to three successive exponential trends. Each trend line is at a lower rate than the one for the preceding period. The one for the period since 1916 is declining. Thus, the trend of trends with respect to patent applications over a 110-year period has been toward progressively lower rates of growth." (Stafford,1952, p.540).

Schmookler (1954) followed Stafford (1952) and analyzed the level of inventive activity using statistics of patents applied for by Americans as a useful indicator of fluctuations in American inventive activity from 1869 to 1938. He also found some ups and downs and credit the patent ratio upward direction to i) the increase in group research, uniting the talents of specialists, may have reduced the number of man-hours required to produce a patentable idea, and ii) the growth of the typical firm increased the likelihood that any particular patentable invention developed within it would be useful, at the same time that it improved the firm's ability to pay the costs of patenting, and the downward direction to i) the complexity of science and technology and the consequent increase difficult to patent and idea, ii) a possible correlation between the size of firms and the propensity to patent, i.e., larger companies could give less attention to small improvements and then weak effort to patent them. Schmookler (1962) gave some steps ahead of his 1954 paper and used a 7-year moving average to give us long time charts of patented inventions in some American industries (railroading, farming, paper making, and petroleum refining) from 1836 to 1957. About railroading, chart 1, p. 200, the patents cover equipment and structures and grow substantially from about 40 in 1840 to about 2000 in 1900, then decline to about 300 in 1940. Petroleum refining, chart 5, p. 216, grew substantially from about 2 in 1855 to between 20 and 30 between 1870 and 1910, then grew from 20 in 1910 to 500 in 1930, then declined to about 200 in 1945. Farming, chart 6, p. 219, grew substantially from 0 in 1840 to 1000 in 1870, swung between 800 and 1000 between 1870-1895, then growth to 1200 in 1910, then down to less than 400 in 1945. And papermaking, chart 7, p. 221, grew substantially from about 100 in 1840 to about 800 in 1930, then declined to about 400 in 1945. More recently, Nicholas (2003) used USPTO patent historical records and found that

between 1908 and 1918 one-quarter of firms were assigned an average of approximately eight patents per year, the highest frequency patenting firm being General Electric (an annual average of 381 patent assignments), and between 1919 and 1928, one quarter of firms were assigned an average of approximately ten patents per year, and the top was Westinghouse (General Electric's chief rival) with an annual average of 404 assignments.

Nevertheless, the long run wave patent debate is not a pacific field, but a controversial debate. Rosenberg and Frischtak (1984), for example, believes that, taken as fluctuations in real quantities, long waves have been understood as ultimately driven either by the process of capital accumulation, as in Kondratiev, or by that of technological innovation, as in the Schumpeterian tradition, with different causality connections: for Kondratiev, technology is consequence of long run waves, for Schumpeter, technology is cause. About the automobilist industry, they point out that the continuing diffusion of an "old" innovation, the automobile, operated as an increasingly powerful stimulus not only in automobiles directly but in a number of ancillary industries such as glass, rubber, metallurgy and petroleum refining. According to Mansfield (1983) the long waves of technological innovation is a reality for some and a science fiction for others. Based on the studies available he concluded that there is no evidence to long waves of innovation, the innovation rate declined between 1970's and 1980's in some industries, but not in others, and there wasn't evidence overall, and there wasn't evidence that depressions tend to trigger innovation. At least, Thompson (1990), in his impressions about long waves, technological innovation, and relative decline, conclude that "Yet for all the appeal (admittedly debatable) of long growth cycles, the base of evidence in support of these fluctuations is less than satisfactory. It sometimes seems that for every study which finds support for the existence of long waves, another study appears and produces empirical evidence denying their existence" (Thompson, 1990, p.201).

In sum, patents have some limits, but it is one of the oldest and widely used sources of information about technology, long run waves is a controversial debate, but it is under discussion for at least 100 years, and long wave patents evidence about automobilist industry is very scarce. In this context, we bring a new set of evidence about internal combustion engine (ICE) long wave patents, from 1900-2019, using

data from Derwent Innovation, a Clarivate Analytics division. ICE goes beyond automobiles, and it considers not only automobiles but also airplanes, boats, ships and industrial machines. Diametrical with the empirical literature about patent long wave, our set of results are consistent, based in a trustable database, quite satisfactory and show the dynamic of ICE patent race through 120 years. After this introduction we present the analytical background, database and results, and our final remarks.

2. ANALYTICAL BACKGROUND

Technical progress endogeneity is a consequence of competition regulation's effect on innovation speed and direction, according to technological standard and path. However, if the standard changes, tech gaps among firms could be reduced or eliminated, once the former advantages are useless in the new paradigm, with new product and process as Utterback (1996) and Dosi (2006) points out. It is clear when offices change from typewriter to computer industry. In this study, the tech standard was that one in the 3rd industrial revolution, specifically microelectronics and Toyotism. It redraws the auto industry market dynamic, new global players in ICE, particularly from Asia.

Paradigms and technological paths help us better understand the auto industry in the long run. Firms and industries in tech developed countries go through a tech path in three phases: fluid, transitory and specific, says Utterback (1996). Fluid means companies adopt a new technology. Product innovation rate is high, there is more radical than incremental innovations, and high-risk failure. Industry reflects firms' behavior and the system is fluid as well. It feedbacks to firms that demand more flexible organizations in this new market environment. Transitory means the old is tiny, firms needed in the new environment are full, and the new command. There was radical process change to fit cost competition, economics of scale became decisive, and the sizable firms got advantages from his production, marketing, management and R&D privileges. Specific means a stable market, with huge price competition, production process automatized, integrated and organized, whose results are almost homogeneous products. Innovation is always possible and the dynamic could be back

any time, as well a new market instability. Dosi (2006) follows Utterback (1996), and he understands that the emergence of new tech paradigms means progress through new tech paths is probably like different supply structures. In the first phase, or the beginning of a new standard, it is normal high Schumpeterian firms' births and deaths. Then it stabilizes in a more balanced and oligopolistic market structure and his barriers to entry, result of private cumulatively and appropriability (Dosi, 2006, p. 139).

Those perceptions help us understand the transition from the 2nd to 3rd Industrial Revolution and the ICE age. From the end of 19th to the beginning of 20th century the auto cars fluid phase was between electric and ICE. Many companies fell down in the transition until ICE was the one in the specific phase, when Ford was the leader company, Fordism the best production process and Model T the main product. Not so far, the market had an oligopolistic structure, with the typical attributes: high barriers to entry and high economies of scale (Utterback (1996), Dosi (2006)). Toyota process innovations, or Toyotism, brought dynamic to the market, as well Information and Communication Technology (ICT), the main 3rd Industrial Revolution sector. There are new restrictions from green agendas, such as regulation, public policies and consumer behavior, and it means adapted or new products in all industries, auto particularly.

At least, we call attention to two paradoxical characteristics of contemporary global economy: i) innovative activity is neither randomly nor uniformly distributed across global, ii) this tendency favoring spatial concentration has become more market over time, not less. In reality, the more knowledge-intensive the economic activity, the more geographically clustered it tends to be. It is because geography is fundamental, not incidental, to the innovation process itself (ASHEIM, GERTLER, 2005). Balland and Rigby (2017) go further and say i) there are "a path-dependent nature of economic evolution locks some regions into technological regimes", ii) "long-run creativity in regions is linked to institutional practices that encourage open knowledge architectures, absorptive capacity, and connections to pools of knowledge generated elsewhere", iii) "the persistence of regional differences in knowledge bases suggests not only that invention is cumulative in nature, resulting from the recombination of existing ideas and from processes of search that tend to be localized, but also that knowledge subsets developed in one location are often difficult to replicate anywhere",

iv) “the cumulative nature of much technological change is limited by the sunk costs of accumulating experience”.

3. RESULTS AND DISCUSSION

We got ICE patent data from 1900 to 2019 from Derwent Innovation, part of Clarivate Analytics group, and applied three filters. The first used the “internal combustion engine” expression in all patent abstracts available. It considers not only automobiles but also airplanes, boats, ships and industrial machines. The second was in the internal patent classification considering groups F01 and F02. And the third considered the subgroup B60K. At least, we mix the three filters’ results in one database. Finally, we used the International Patent Documentation (INPADOC) function and got 675.172 ICE related patents. We organized it in time (decades), space (countries), and trademarks. Tables 1A,1B,1C give us a broad perspective.

Tables 1A has the total ICE patent records, by country and decade. Call attention total ups and downs through 12 decades: about 5 thousand in 1900’s, 17 thousand in 1910’s, 6 thousand in 1920’s and 1940’s and 7 thousand in 1930’s, 11 thousand in 1950’s, 12 thousand in 1960’s, astonish 72 thousand in 1970’s, 66 thousand in 1980’s, 43 thousand in 1990’s, 76 thousand in 2000’s and incredible 353 thousand in 2010’s, or 52% of 675 thousand of patents in those 120 year records. And from 1970’s to 2010’s we have 90% of the records.

Table 1B gives us the distribution by country in each decade. In 1900’s France (73%) and the UK (22%) had 95% of ICE patents. In 1910’s USA (20%) joint the club, and mutual relations with France (33%) and UK (40%) had 93% of the total. In 1920’s Germany alone had 77%, in 1930’s and 1940’s only USA had 73% and 70%, respectively. In the 1950's USA (37,3%) and Germany (46,5%) had 84% of the total, and in 1960’s Germany (50%) and UK (23%) had 73%. In the 1970's and 1980’s Japan was in the same position as Germany in the 1920's with 74% and 76% share, respectively. In the 1990's Japan (57%) and Germany (22%) had 79% of the total, and in 2000’s and 2010’s China got the podium, but neither country had more than 40% share.

At least, Table 1C gives us each country's effort distribution through the 12 decades, and it is clear that China ICE patent effort is recent, with 96% in 2010's, as well as the USA (60%), South Korea (70%) and Russia (55%). Japan, Germany and France efforts were concentrated in other decades, and the UK particularly had 70% of his ICE records in 1910's, 1960's and 1970's. It is also important to mention no records for France from 1920's to 1960's and UK from 1920's to 1940's and in the 1980's and 1990's.

This set of data makes it clear that ICE patent effort migrates from Europe to Asia, that the UK gets out from this game, and that country concentration in some periods and unpresented in others reflect part patent store, part national industrial strategy. The UK for example changes from industry to services. It also suggests that Utterback (1996) three phases (fluid, transitory and specific) are quite different in each of the main countries, with reflection in the global patent dynamic game.

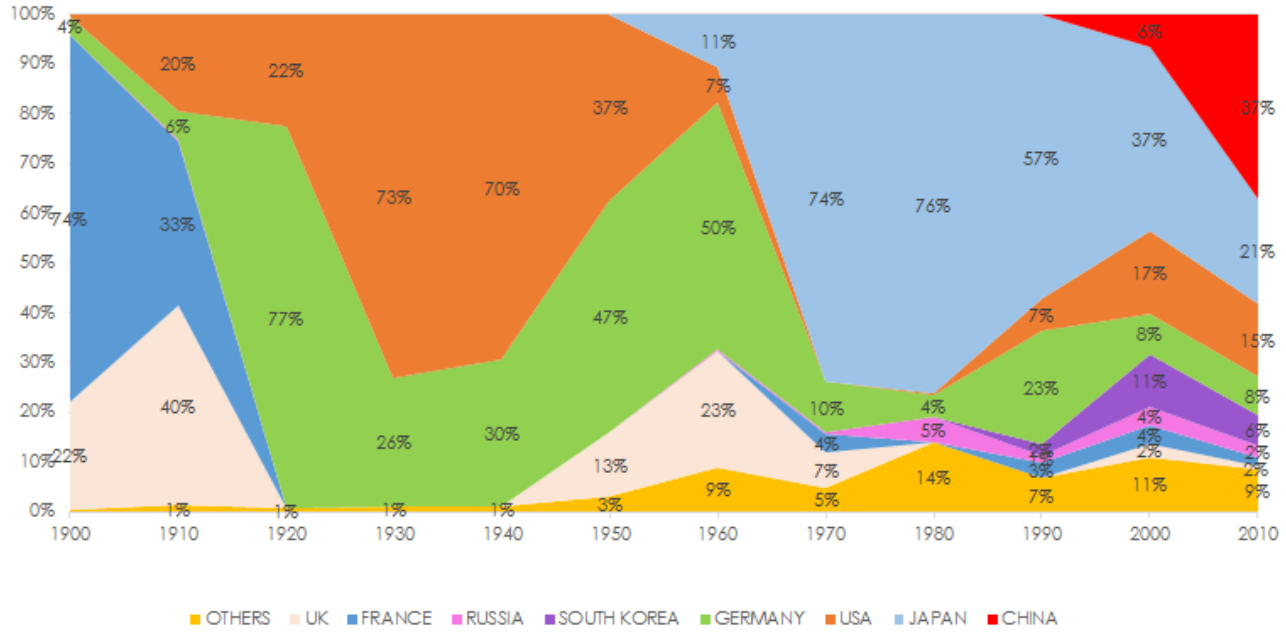
GRAPH 1 completes TABLES 1A,1B, 1C. It is a clear ICE patent cycle that began in 1900's concentrated in France and the UK. Between 1920's and 1950's, Germany and USA swing lead, until Japan joins the game in 1960's. Japan was the first until 2000's, and then China got the first place in 2010's.

TABLES 1A,1B,1C: ICE patents records, time and space distribution

TABLE 1A	1900	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000	2010	Total
CHINA	0	0	0	0	0	0	0	0	21	75	4.955	131.610	136.661
JAPAN	0	0	0	0	0	0	1.299	53.028	50.445	24.449	28.273	74.300	231.794
USA	13	3.398	1.340	5.086	4.223	4.007	838	29	136	2.857	12.651	52.520	87.098
GERMANY	201	1.000	4.593	1.781	1.794	5.004	6.059	7.337	2.924	9.688	6.439	27.440	74.260
SOUTH KOREA	0	0	0	0	0	0	0	0	33	1.025	8.024	21.290	30.372
RUSSIA	0	12	0	0	0	0	9	88	3.336	603	2.855	8.364	15.267
FRANCE	3.842	5.768	0	0	0	0	2	2.709	13	1.345	2.867	6.183	22.729
UK	1.145	6.952	0	0	0	1.413	2.844	5.179	11	33	1.908	2.046	21.531
OTHERS	18	216	33	80	58	315	1.090	3.473	9.258	2.900	8.304	29.715	55.460
TOTAL	5.219	17.346	5.966	6.947	6.075	10.739	12.141	71.843	66.177	42.975	76.276	353.468	675.172
TABLE 1B	1900	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000	2010	
CHINA	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,032%	0,175%	6,496%	37,234%	
JAPAN	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	10,699%	73,811%	76,227%	56,891%	37,067%	21,020%	
USA	0,249%	19,590%	22,461%	73,211%	69,514%	37,313%	6,902%	0,040%	0,206%	6,648%	16,586%	14,858%	
GERMANY	3,851%	5,765%	76,986%	25,637%	29,531%	46,597%	49,905%	10,213%	4,418%	22,543%	8,442%	7,763%	
SOUTH KOREA	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,050%	2,385%	10,520%	6,023%	
RUSSIA	0,000%	0,069%	0,000%	0,000%	0,000%	0,000%	0,074%	0,122%	5,041%	1,403%	3,743%	2,366%	
FRANCE	73,616%	33,253%	0,000%	0,000%	0,000%	0,000%	0,016%	3,771%	0,020%	3,130%	3,759%	1,749%	
UK	21,939%	40,078%	0,000%	0,000%	0,000%	13,158%	23,425%	7,209%	0,017%	0,077%	2,501%	0,579%	
OTHERS	0,345%	1,245%	0,553%	1,152%	0,955%	2,933%	8,978%	4,834%	13,990%	6,748%	10,887%	8,407%	
TOTAL	100,000%	100,000%	100,000%	100,000%	100,000%	100,000%	100,000%	100,000%	100,000%	100,000%	100,000%	100,000%	
TABLE 1C	1900	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000	2010	Total
CHINA	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,015%	0,055%	3,626%	96,304%	100,00%
JAPAN	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,560%	22,877%	21,763%	10,548%	12,197%	32,054%	100,00%
USA	0,015%	3,901%	1,538%	5,839%	4,849%	4,601%	0,962%	0,033%	0,156%	3,280%	14,525%	60,300%	100,00%
GERMANY	0,271%	1,347%	6,185%	2,398%	2,416%	6,738%	8,159%	9,880%	3,938%	13,046%	8,671%	36,951%	100,00%
SOUTH KOREA	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,000%	0,109%	3,375%	26,419%	70,097%	100,00%
RUSSIA	0,000%	0,079%	0,000%	0,000%	0,000%	0,000%	0,059%	0,576%	21,851%	3,950%	18,700%	54,785%	100,00%
FRANCE	16,904%	25,377%	0,000%	0,000%	0,000%	0,000%	0,009%	11,919%	0,057%	5,918%	12,614%	27,203%	100,00%
UK	5,318%	32,288%	0,000%	0,000%	0,000%	6,563%	13,209%	24,054%	0,051%	0,153%	8,862%	9,503%	100,00%
OTHERS	0,032%	0,389%	0,060%	0,144%	0,105%	0,568%	1,965%	6,262%	16,693%	5,229%	14,973%	53,579%	100,00%
TOTAL	0,773%	2,569%	0,884%	1,029%	0,900%	1,591%	1,798%	10,641%	9,802%	6,365%	11,297%	52,352%	100,00%

Author's elaboration from Derwent Innovation, 2021

GRAPH 1: ICE patents records share, main countries and decades.



Author's elaboration from Derwent Innovation, 2021

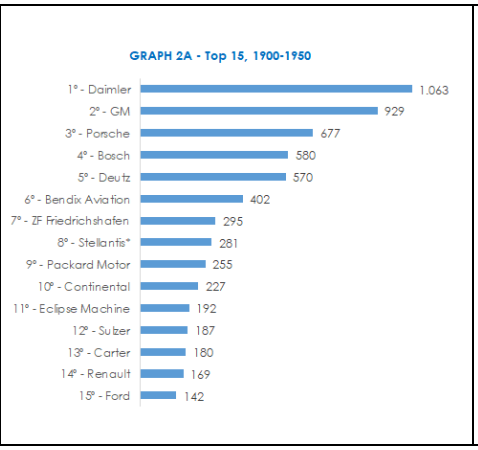
We also organized the data considering trademarks. GRAPHS 2 A,B,C allows see the ICE records distribution under firm perspective. From 1900-1960, top 15 had European an American companies only, and top 5 (Daimler, GM, Porsche, Bosch, Deutz) had 62% of total patents (Graph 2A), from 1960-1990 Japanese companies joint the club, and top 5 (Bosch, Toyota, Nissan, Hitachi, Honda) had 54% of the total (Graph 2B), and from 2000-2010 the leading companies are also American, European and Japanese, and top 5 (Toyota, Bosch, Honda, Denso, Porshe) had 56% of total.

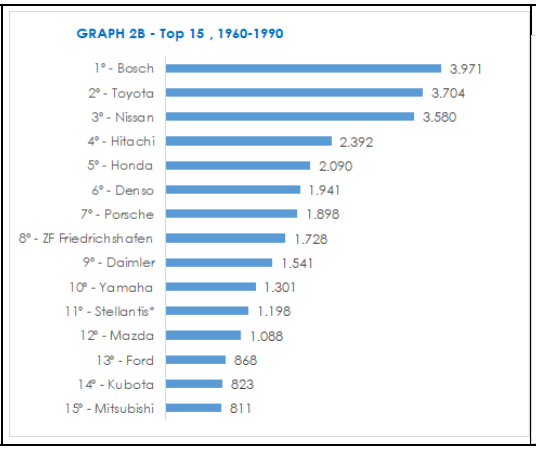
ICE vehicles production, in some way, follows ICE patent records, and it doesn't sound a coincidence. In 1900 were made in USA 369,5 thousand vehicles. It jumped to 8,2 million in 1910. Economics of scale increase result in market concentration. In this oligopolistic sector Ford got the podium and 7/10 vehicles made in the USA in 1914 had Henry trademark. In the 1920's 27,7 million vehicles were made in the USA, and in a neck-neck competition General Motors (28%) shared the first place with Ford (27%), says Wards Intelligence (2021). GM growth is partially explained by Alfred Sloan GM portfolio diversification (it offers 5 options to consumers, Ford only model T) and decentralized management. And Japanese firms' global increase since 1970's is the result of Toyota's flexible production concept, later used by other Japanese companies (WOOD JR, 1992).

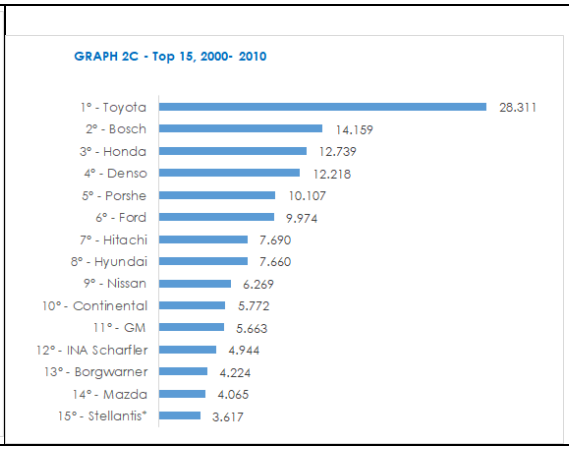
GRAPH 3, based on Organisation Internationale des Constructeurs d'Automobiles (OICA, 2021) data, gives us a clear picture of this dynamic global market. In the 1950's 77% of the vehicles made in the world were made in the USA. Then USA global share decreased to 48% in 1960's, 28% in 1970's, about 20% in 1980's, 1990's and 2000's, and about 10% in 2000's and 2010's. Japan did well from 1970's to 2000's, about 1/5 global production, and China was the leader in 2010's, with 1/3 of global share. According to American Enterprise Institute (AEI, 2019) Asia companies have been in the American market since 1970, when Toyota and Nissan had 1,4% and 1% of USA market share. In 1975 all Japanese companies in the USA (Toyota, Nissan, Honda, Subaru) had 5,6% market share, it jumped to 15,6% in 1985, and 18,1% in 1990. In 2000's South Koreans arrived, and Hyundai and Kia got 1,4% of the American vehicle market,

and Toyota got GM's first global production place. In 2010 Toyota had 16,2% USA share, and all Japanese companies in the USA had 36,4% of American share. Reuters (2022) inform us of an historical record in 2021. For the first time since 1931 another company other than GM, Toyota, took first place in the USA. Automobilist global market changes also reflected on America.

GRAPH 2 A,B,C: trademark ICE records distribution

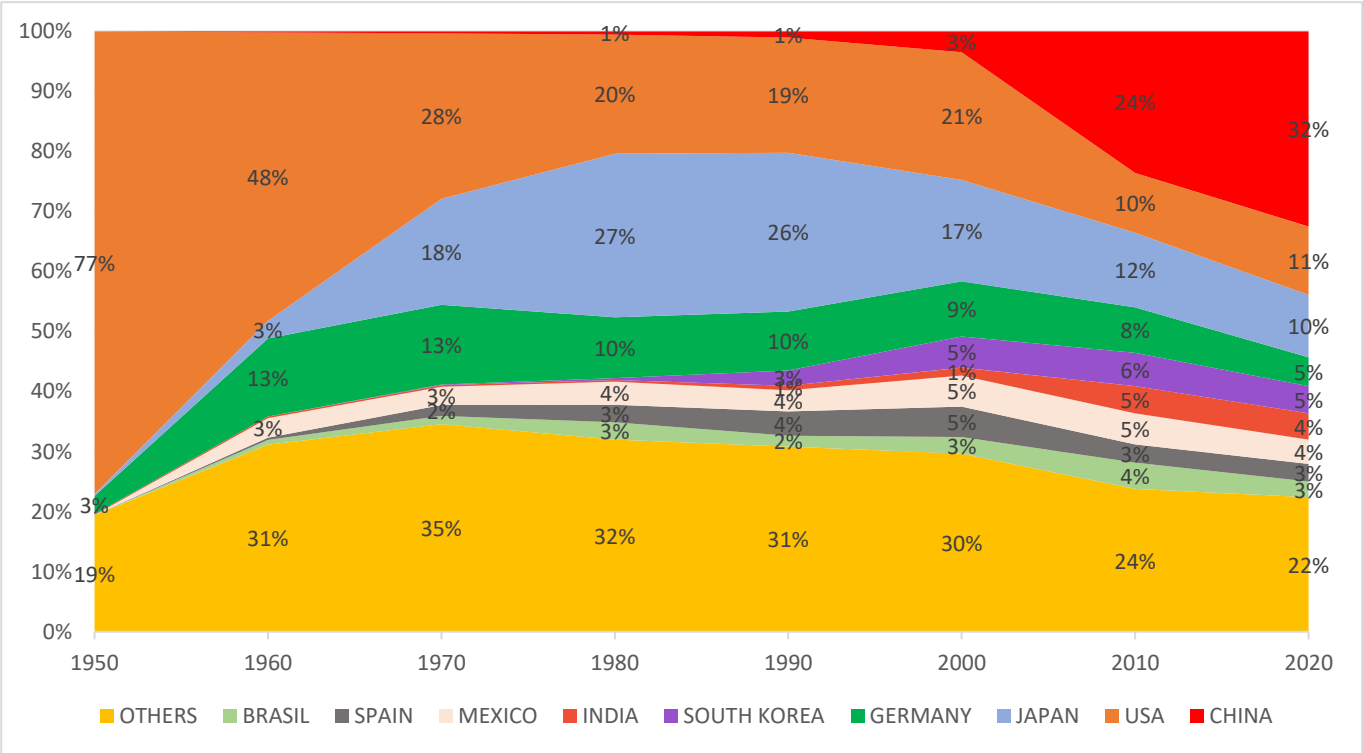






Author's elaboration from Derwent Innovation, 2021. Stellantis sum up FIAT, Chrysler, Dodge, RAM, Peugeot e Citroen for all periods.

GRAPH 3: Country ICE global share production, 1950-2020



Author's elaboration from OICA (2021)

FINAL REMARKS

In the introduction, we show that patent, long wave and long wave patent is an old and controversial debate, with few studies about internal combustion engine (ICE) long wave patents. In the analytical background we sum up the relation between technical progress and market dynamic, and highlight the paradoxical characteristics of contemporary global economy. And in the result section we detailed 675 thousand ICE patent record distribution through 120 years under a time (decades), space (country) and trademark perspective. This set of data makes it clear that ICE patent effort migrates from Europe to Asia, that the UK gets out from this game, and that country concentration in some periods and unpresented in others reflect part patent store, part national industrial strategy. The UK for example changes from industry to services. It also suggests that Utterback (1996) three phases (fluid, transitory and specific) are quite different in each of the main countries, with reflection in the

global patent dynamic game. It is not a surprise to lead firms from the lead countries. In fact, it is the firm's performance that gives the country a lead position. ICE patents records fit well with vehicle production sales. At least, ICE is a hot subject in this geo political moment, with green agenda under fire. Some people believe that electric mobility is the only option, but there is a long tradition and some options in combustion engines.

REFERÊNCIAS

AMERICAN ENTERPRISE INSTITUTE. **Animated chart of the day: market shares of US auto sales, 1961 to 2016**. [S. l.], 2019. Disponível em: https://www.aei.org/carpe-diem/animated-chart-of-the-day-market-shares-of-us-auto-sales-1961-to-2016/. Acesso em: [inserir data de acesso].

ASHEIM, B. T.; GERTLER, M. S. The geography of innovation: regional innovation systems. In: FAGERBERG, J.; MOWERY, D. C.; NELSON, R. R. (ed.). **The Oxford handbook of innovation**. Oxford: Oxford University Press, 2005. p. 291-317.

BALLAND, P.; RIGBY, D. The geography of complex knowledge. **Economic Geography**, v. 93, n. 1, p. 1-23, 2017.

COHEN, W. L.; NELSON, R. R.; WALSH, J. P. **Protecting their intellectual assets: appropriability conditions and why U.S. manufacturing firms patent (or not)**. Cambridge, MA: National Bureau of Economic Research, fev. 2000. (NBER Working Paper, n. 7552).

COMINO, S.; GALASSO, A.; GRAZIANO, C. Market power and patent strategies: evidence from Renaissance Venice. **The Journal of Industrial Economics**, v. 68, n. 2, p. 226-269, 2020.

DERWENT INNOVATION. [S. l.: s. n.], 2021. Disponível em: https://www.derwentinnovation.com. Acesso em: [inserir data de acesso].

DOSI, G. **Mudança técnica e transformação industrial: a teoria e uma aplicação à indústria dos semicondutores**. Campinas: Unicamp, 2006.

GRILICHES, Z. Patent statistics as economic indicators: a survey. **Journal of Economic Literature**, v. 28, n. 4, p. 1661-1707, dez. 1990.

KONDRATIEFF, N. D.; STOLPER, W. F. The long waves in economic life. **The Review of Economics and Statistics**, v. 17, n. 6, p. 105-115, nov. 1935.

MANSFIELD, E. Long waves and technological innovation. **The American Economic Review**, v. 73, n. 2, p. 141-145, maio 1983. Papers and Proceedings.

NICHOLAS, T. Why Schumpeter was right: innovation, market power, and creative destruction in 1920s America. **The Journal of Economic History**, v. 63, n. 4, dez. 2003.

ORGANISATION INTERNATIONALE DES CONSTRUCTEURS D'AUTOMOBILES. **Sales statistics**. [S. l.], 2021. Disponível em: https://www.oica.net/category/sales-statistics/. Acesso em: [inserir data de acesso].

REUTERS. **Toyota dethrones GM as U.S. sales leader after nearly a century on top**. [S. l.], 4 jan. 2022. Disponível em: https://www.reuters.com/business/autos-transportation/toyota-poised-dethrone-gm-2021-us-sales-leader-2022-01-04/. Acesso em: [inserir data de acesso].

ROSENBERG, N.; FRISCHTAK, C. R. Technological innovation and long waves. **Cambridge Journal of Economics**, v. 8, n. 1, p. 7-24, mar. 1984.

SCHMOOKLER, J. The interpretation of patent statistics. **Journal of the Patent Office Society**, v. 32, n. 2, p. 123-146, fev. 1950.

SCHMOOKLER, J. The utility of patent statistics. **Journal of the Patent Office Society**, v. 35, n. 6, p. 407-412, jun. 1953a.

SCHMOOKLER, J. Patent application statistics as an index of inventive activity. **Journal of the Patent Office Society**, v. 35, n. 7, p. 539-550, ago. 1953b.

SCHMOOKLER, J. The level of inventive activity. **The Review of Economics and Statistics**, v. 36, n. 2, p. 183-190, maio 1954.

SCHMOOKLER, J. Changes in industry and in the state of knowledge as determinants of industrial invention. In: NATIONAL BUREAU COMMITTEE FOR ECONOMIC RESEARCH. **The rate and direction of inventive activity: economic and social factors**. Princeton: Princeton University Press, 1962. p. 195-232.

STAFFORD, A. B. Is the rate of invention declining? **American Journal of Sociology**, v. 57, n. 6, p. 539-545, maio 1952.

THOMPSON, W. R. Long waves, technological innovation, and relative decline. **International Organization**, v. 44, n. 2, p. 201-233, 1990.

UTTERBACK, J. **Dominando a dinâmica da inovação**. Rio de Janeiro: Qualitymark, 1996.

WARDS INTELLIGENCE. [S. l.: s. n.], 2021. Disponível em: https://wardsintelligence.informa.com/datacenter. Acesso em: [inserir data de acesso].

WOOD JR., J. Fordismo, toyotismo e volvismo: os caminhos da indústria em busca do tempo perdido. **RAE - Revista de Administração de Empresas**, 1992.

NOTAS

Endereço de correspondência do principal autor
Universidade Federal de Santa Catarina, Campus Trindade, Centro Sócio Econômico, CEP 88040-900.

AGRADECIMENTOS
Agradecemos o Editor e os pareceristas pelos comentários e sugestões.

CONTRIBUIÇÃO DE AUTORIA
Os papéis descrevem a contribuição específica de cada colaborador para a produção acadêmica inserir os dados dos autores conforme exemplo, excluindo o que não for aplicável. Iniciais dos primeiros nomes acrescidas com o último Sobrenome, conforme exemplo.

Concepção e elaboração do manuscrito:
Gilson Geraldino Silva Júnior, Marcelo Arend, Thiago Rodrigues Lemos
Coleta de dados:
Thiago Rodrigues Lemos
Análise de dados:
Gilson Geraldino Silva Júnior, Marcelo Arend, Thiago Rodrigues Lemos
Discussão dos resultados:
Gilson Geraldino Silva Júnior, Marcelo Arend, Thiago Rodrigues Lemos
Revisão e aprovação:
Gilson Geraldino Silva Júnior, Marcelo Arend, Thiago Rodrigues Lemos

FINANCIAMENTO
Não houve financiamento.

CONSENTIMENTO DE USO DE IMAGEM
Não se aplica.

APROVAÇÃO DE COMITÊ DE ÉTICA EM PESQUISA
Não se aplica.

CONFLITO DE INTERESSES
Não há conflito de interesses.

PUBLISHER
Universidade Federal de Santa Catarina. Programa de Pós-Graduação em Educação Física. LaboMídia - Laboratório e Observatório da Mídia Esportiva. Publicado no Portal de Periódicos UFSC. As ideias expressadas neste artigo são de responsabilidade de seus autores, não representando, necessariamente, a opinião dos editores ou da universidade.

EDITORES
Ronivaldo Steingraber