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**The emergence of parallel trajectories in the automobile industry:
Environmental issues and the creation of new markets**

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The emergence of parallel trajectories in the automobile industry. Environmental issues and the creation of new markets.

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Abstract

In the past few years we have witnessed how traditional manufacturing relationships between North and South are rapidly changing and allowing for new forms of interaction. This article suggests that we are facing, on the one hand, a disruption of the traditional markets guided by traditional industries towards the creation of new industries and consequently new markets. The study proposes the co-existence of three, not-yet competing, trajectories: (i) the traditional one between Original Equipment Manufacturers (OEMs) and their subsidiaries in the South, (ii) the emerging South (with China and India) investing and acquiring OEMs from the North, (iii) the race for the development of environmentally friendly technologies, pushed by public policy and promoted by heavy public R&I funding; linked to the promotion by the North of new industries. The implications of the interaction of these trajectories are not yet clear. However, it seems that at least in the current stage of pre-competitive capabilities building, collaboration among firms (in any of its forms) rather than competition is proven to be more efficient in reaching technological mastery. The question of how the South will position itself in the new emerging order is still an open one.

Key words: mobility, environment, automobile industry, innovation, H2020, supply chain management

JEL classification codes: O330, L62, L500

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Introduction

In recent years we have witnessed how traditional manufacturing relationships between North and South are rapidly changing and allowing for new forms of interaction. On the one hand, the industrial restructuring processes of emerging countries, as well as their increasing investment in the North in search of technological upgrades, suggest not only a significant acquisition of technological capabilities in the South but the restructuring of the global value chain as we traditionally know it. On the other hand, we see an important push towards increasing environmental regulations and the creation and strengthening of new (green) technologies and industries in the North, strongly supported and financed by the H2020 framework.

The implications of these phenomena on the restructuring of the global value chain are still uncertain but nevertheless of high socio-economic relevance. Attention to the first phenomenon has been brought, among others, by UNCTAD (2012), Jullien and Pardo (2015) and Chaminade, Rabelloti, Martinelli, Giuliani, Alvandi, Amendolagine, Amighini, Cozza, Dantas, Hansen, Liu, Lv, Meyer, Moskovko, Parthasarathy, and Scalera (2015), who highlight the significant participation of China and India, along with other emergent economies, in the global industrial value chain, as well as the beginning of FDI flows from South to North. The second trend is mostly documented in reports and working papers by the European Commission and the UK government. Authors like Montalvo and Leijten (2015) and Mazzucato, Cimoli, Dosi, Stiglitz, Landesmann, Pianta, Walz, and Page (2015) have addressed the issues of this latter phenomenon, which is characterised by the search for new markets based on the development of technologies that comply with the increasing environmental rules and regulations imposed by the North.

By taking up the example of the automotive industry, this research presents an exploratory overview of these recent developments in the global context. Due to its high levels of globalisation and technological requirements, the automotive industry is frequently used as a case study to illustrate learning and innovation paradigms between OEMs, their subsidiaries and domestic parts suppliers. The high levels of employment

that the industry creates in both the South and the North reinforce the socio-economic significance of the industry as a case study.

This research argues that the automobile industry – like other manufacturing activities – is embedded in a network of at least three different, but not competing, trajectories. What the paper calls the first trajectory includes the much-analysed learning and innovation relationships between OEMs and their subsidiaries in the South. A diverse selection of case studies of the interactive learning and capability building literature shows how firms in the South have learned to innovate over the past decades, as well as how the domestic support industries have failed to integrate at the expected rate and intensity. The second trajectory consists of the recent learning and innovation efforts of firms in the South geared towards acquiring state-of-the-art technology. These efforts, which are giving rise to what the literature is calling technology-driven FDI (TFDI), are led by China, India and Brazil, among other emerging countries.

The paper indicates a third trajectory in which countries of the North are continuously presented with emerging technological paradigms in light of the increasing global environmental regulations. This trajectory includes the emergence of electric and hybrid cars, among others. This trajectory is closely connected to the creation of new technologies and the promotion of the machine tools sector. This trajectory targets the global advantages of replacing existing technologies and supply chains with new ones.

The paper is organised as follows: The following section presents a brief background of the automobile industry. Section 3 discusses the first trajectory, the learning and innovation of OEM's subsidiaries in the South, including arguments in the catching-up literature. Section 4 presents cases of the TFDI of automobile firms of the South in the North. Section 5 presents an overview of the main emerging automotive technologies (e.g. green vehicles and clean energy sources), which constitute trajectory three. This section gives an overview of the main projects financed by the European Commission under the H2020 framework. Section 6 concludes with a brief discussion and potential implications.

The automotive industry

The automobile industry is a unique example of an industry with high levels of globalisation and technological complexity. It serves as a stereotypical case study of an industry with high levels of investments by its main assemblers (i.e. OEMs) in their overseas manufacturing activities. From the South's perspective, it represents an example of an industry that, while located in a developing country, is shaped by international organisational and technological standards. The wide set of interrelations with other local industrial activities, technological requirements and dependence for parts and components is assumed to stimulate the technological development and upgrading of its supporting industries, which increases its attractiveness to countries hosting its subsidiaries (Barnes and Kaplinsky, 2000; Lorentzen, 2005; Parhi, 2006). This is a sector that allows emerging economies to develop capabilities that, in turn, enable them to enter other sectors with less technological stability (Chaminade et al, 2015).

During the last decades, the organisational and production strategies followed by the auto industry worldwide have undergone important changes, impacting product and process innovation in supplying industries and in the auto industry itself. The employment generated by the industry is also a factor to consider when discussing its relevance. In Europe, there are about 12 million jobs created by this sector (European Commission, 2014).

Trajectory one: OEMs' subsidiaries in the South

The industrialisation arguments in the South, inspired by the East Asian industrialisation example of the 1960s and 1970s, with its focus on technological capability building – and strengthening – act as a trigger for development. The interactive learning and capability building literature highlights trade as a mechanism through which exporting firms increase their productivity through learning from participating in international markets (Bank, 1998; Galina & Murat, 2004). The arguments state that exporting firms (and those related to them) learn by changing their production, distribution and

organisational procedures to better match those at international levels (Bonelli, 2000; Macario, 1999, 2000; Macario, Bonelli, Ten Kate, & Niels, 2000).

In the early 1960s, initially motivated by low wages in the South, we observed an increasing number of inbound plants (i.e. maquiladoras) being established in countries of the South. Since then, industries such as automobiles and electronics have been the key industries that the countries in the South want to attract, due to the nature of their linkages with other industries (e.g. steel, electronics, plastics) and the high levels of employment that these industries bring.

Through empirical analysis, and considering the firm as the unit of analysis, the interactive learning and capability building literature has richly illustrated how what in the early years of industrialisation were mostly assembling operations with high levels of low-cost labour and low local content integration moved towards more complex learning and technological dynamics, giving important lessons in the evolution of the industrialisation process in the South. This is documented by a large number of case studies illustrating the constant evolution of latecomer firms during the dynamic industrialisation period preceding trade liberalisation and the large privatisation process in many countries of the South.

The systems of innovation (SI) approach, with its classifications of national (Lundvall, 1992), sectoral (Malerba, 2002) and local (Cassiolato & Lastres, 1999), gave us a new direction for understanding learning and innovation as dependent elements embedded in a network of institutions (formal and informal) and private and public stakeholders. The SI approach shifted the focus from the profit maximisation and market variables traditional in neoclassical economics to the interaction among the system's actors (e.g. knowledge products and users), understanding innovation as a dynamic and inclusive process (Mytelka, 2000).

Departing from the literature on technological capability at the technological frontier, the building of technological capabilities in latecomer firms surged as a way to understand the processes in which firms in developing countries learn and innovate (Bell, 1984; Bell & Pavit, 1995; Katz, 1987; Lall, 1990). This parallel study of how firms in different contexts learn and upgrade their capabilities makes clear the difficulty of comparisons

and blueprints, as the macro and meso environments of both approaches are fundamentally different.

Studies illustrating the technological efforts made by manufacturing firms in order to achieve technological capabilities, such as those of Jonker, Romijn, and Szirmai (2006) and Romijn (1997) are just a sample of the level of detail reached by this branch of literature. In the case of the automobile industry, the studies of Carrillo and Ramirez (1990), Carrillo and Hualde (1996), Lara and Carrillo (2003) and Carrillo and Lara (2004) show the process by which the inbound industry in Mexico (as in many other countries) grew from simple assembling operations to manufacturing, then to design and research, and then to intra- and inter-firm coordination through the host country, with a strong engineering system supporting the interaction. Vallejo (2010) presents a taxonomy of learning mechanisms for Mexican domestic auto parts firms over time, showing changes in the choice of learning tools adopted by firms over time and under changing conditions. These studies (and many others) explain aspects at the micro level of how firms build and strengthen their technological capabilities. These studies are complemented by meso-level initiatives in which the 'catching-up' with the North is the main aim of the analysis.

From the lessons learned in these studies, it is clear that to build and strengthen innovation capacity (the utmost goal), all stakeholders have to be involved and the relevant expertise needs to be built according to the trends of the industry at the global level, not at the local one. We have learned that the ability to handle processes of technological, organisational and technical change is the key difference between firms in the North and in the South.

The following sections provide an overview of the ongoing international trends in the global automobile industry. After all, it is only by building the necessary knowledge to understand the implications of the global trends and efforts that the South can engage in the institutional change required to design industrial policies that promote sustainable learning and development in its industries.

Trajectory two: Technology FDI from South to North

Examples of common acquisitions in the automobile industry are the Renault alliance with Nissan in 1999 and its later acquisition of Isuzu, as well as the heavy exchange of capital stakes with Fiat. In 2011 Daimler AG and Robert Bosch GmbH signed a joint venture agreement for the development, production and sale of traction motors for electric vehicles. Other alliances that are worth mentioning are those of the VW Group and the GM alliance. The first one involves 12 brands from 7 European countries, namely VW passenger cars and VW commercial vehicles, Audi, SEAT, SKODA, Bentley, Bugatti, Lamborghini, Porsche, Ducati, Scania and MAN (<http://www.volkswagenag.com>). The second one includes Chevrolet and Cadillac, Baojun, Buick, GMC, Holden, Isuzu, Jiefang, Opel, Vauxhall and Wuling (<http://www.autoalliance.org>).

Although these mergers and acquisitions (M&A) among large OEMs (as well as their breakups) are becoming more and more common as a way to increase market share and to address technological changes, M&A between developed MNCs and those from developing countries (called 'emerging multinationals' in the literature) are a recent phenomenon.

Two cases have been explored in the literature, the acquisition of Jaguar Land Rover by Tata Motors (India) in 2008 and the acquisition of Volvo and Saab by Chinese automotive groups. These events suggest that Chinese and Indian firms have evolved and are following different learning and innovation directions than those firms presented in trajectory one. The following sections will present insights into the evolution of these firms.

India

The economic reforms started in India in 1983, and the trade liberalisation of 1991 opened the Indian market to local and foreign competition. As in the case of many other developing countries, foreign firms were attracted to industries such as electronics, ICT and automobiles under the major liberalisation process. This foreign intervention came mostly in the form of FDI and joint ventures (JV).

The Indian automotive industry in the 1980s consisted of a large number of small domestic, and inefficient, auto parts firms. With the entrance of global competitors due to the massive liberalisation started in the 1990s, along with the local content requirements imposed by the government, the industry was pushed to develop inter-firm linkages. The combination of factors brought about by trade liberalisation and the growing Indian middle class contributed to the rapid growth of the industry, making India the fifth largest producer of vehicles among developing countries (ACMA, 2000).

Two Indian OEMs led the domestic market: Maruti Udyog Ltd (MUL) and Tata Engineering & Locomotive Co. Ltd (TELCO). The first one is a JV between the Indian government and Suzuki Motors Corp of Japan. The second one is a large domestic firm owned by the largest Indian conglomerate, the Tata Group.

The local content requirements imposed by the government and the high duty fees on imported products pushed the industry to invest in strengthening the local auto parts sector, which consisted of a large number of small-scale informal firms and about 400 formal ones (AIAM, 1999). Competition based on imported components was ruled out based on their high prices. Therefore, with the entrance of 13 global OEMs and their first-tier suppliers (e.g. Delphi, Lucas TVS and Denso), large inflows of FDI went toward strengthening and upgrading the production capabilities of the component industry². By the mid-1990s large business groups (e.g. Tata and Birla) had formed JVs with global suppliers to produce key parts components (ACMA, 1995).

Despite the technological investments to strengthen the capabilities of the auto parts sector, by the late 1990s there were first-tier suppliers, a few second-tier and almost no third-tier ones. In many cases, small-scale subcontractors with very specific descriptions of the job required were doing the job of third-tier suppliers (Okada, 2004).

Okada (2004) presents an analysis of the skills development and inter-firm learning linkages behind the development of MUL and TELCO's first-tier suppliers. Due to the reliance of assemblers on domestic auto parts producers, the former increased their efforts to upgrade the production quality of the latter. Okada (2004) identifies how these

² GMI, Ford, Mercedes-Benz and Toyota encouraged their first-tier suppliers to start operations in India and to promote JVs with local suppliers ACMA (1995).

firms upgraded their production and managerial skills by hiring workers with higher levels of education. At the manager level, Okada (2004) identifies a shift in the preferences for MBAs graduates and qualified managers over family members due to the expanding interest of the firms, the exposure to Japanese business culture brought by MUL and Honda and the need to obtain ISO certificates as required by their customers.

Inter-firm linkages and the role of leading firms shaped the patterns of skills development of the suppliers. Okada (2004) also found that in the Indian context, knowledge and skill diffusion is explicit, standardised and codified, which facilitates diffusion within the supply chain.

In their study of technology management practices, Husain, Sushil, and Pathak (2002) present three cases of Indian auto firms (i.e. Telco, Hindustan Motors Ltd. and Eicher Motors Co.) collaborating with foreign firms for technology acquisition. Their study shows that the effectiveness of collaboration is dependent on the firms' absorptive capacity. JVs bring foreign investment and a commitment for technology transfer. However, the technology transferred is not state-of-the-art but rather mature or obsolete technology. This is not of relevance to the technology recipient, as long as there is a market for the products produced with such technologies.

In their analysis, Husain et al. (2002) describe Telco as a firm that on the one hand promotes the development of its own technological bases and, on the other hand, is quick in acquiring state-of-the-art technology from abroad. The first international collaboration of Telco was with Mercedes to manufacture HVCs in India. After that association ended, Telco entered other technical and financial collaboration agreements with Mercedes Benz India Limited (MBIL) to manufacture the E220 series in India, aiming to capture part of the growing domestic market for luxury cars. Telco also started in 1994 a JV partnership with Cummins to manufacture diesel engines for LCVs and HCVs. In 1995, Telco started two JVs abroad, one with Tata Precision Industries manufacturing precision tools and metallic and plastic components in Singapore and the other called Nita Company Limited assembling Telco vehicles in Bangladesh (Husain et al., 2002).

Husain et al. (2002) describe Telco as the only Indian firm that, by borrowing need-based state-of-art technologies from foreign firms, is able to do product design in India. The authors present the learning path undergone by Talco and explain how even though the firm was not able to reach the excellence level of international firms, it developed technological capabilities that allowed it to compete in its domestic market.

Talco's experience and absorption capacity allowed the firm to acquire technologies abroad and to strengthen its domestic base. In 2004, Tata Motors acquired the heavy vehicles unit of Korean Daewoo Motors. In 2005, Tata Steel acquired Singaporean NatSteel. In the same year, Tata Chemicals bought the majority of shares of the UK Group Brunner Mond. Corus (UK-NL) was acquired by Tata Steel in 2007 (www.tatamotors.com).

Perhaps the most oft-mentioned of Tata Motors' acquisitions is that of Jaguar and the Land Rover brands in 2008 from Ford Motors (Carty, 2008).³ After agreeing to pay US 2.3 billion for both brands, Tata Motors stepped out as a global player in the automobile industry. In 2013 both brands were officially joined to form Jaguar Land Rover (JLR).

Within a couple of years after the acquisition of JLR by Tata, most relevant financial magazines were already publishing the duplication of JLR sales and an increase of five times of its financial valuation compared to its last year under Ford's ownership (Rapoza, 2012).

Based on in-depth interviews with key informants and patent data from these three companies, Borah, Karabag, and Breggen (2015) present a comparison of the market performance of JLR under Ford and under Tata Motors. The authors explore the post-acquisitions strategies adopted by Tata Motors and compare them with those of Ford. Borah et al. (2015) identify three critical factors behind JLR's improvement in performance. First, in direct contrast to Ford, which kept an integrated strategy with JLR, Tata implemented a separate strategy in most business functions (i.e. human resources, marketing, production and product development). Second, Tata invested heavily in JLR business functions. The timing of the acquisition of JLR also played a

³ Ford acquired Jaguar in 1989 for US 2.5 billion and later acquired Land Rover from BMW in 2000 for US 2.8 billion (<http://www.jaguarlandrover.com/gl/en/about-us/our-history>).

role in the improved performance of JLR. Borah et al. (2015) find a correlation between the growing Chinese market and the product pipeline inherited from Ford.

In their study of knowledge flows between emerging multinationals investing in developed ones, Chaminade et al. (2015) find similar insights in the Indian case. The authors find a flow of R&D knowledge from Europe towards the manufacturing plants in India.

China

After a period of decreasing sales and serious losses, Volvo was sold by Ford Motor to Zhejiang Geely Holdings of China (known as Geely) in 2010 for US 1.8 billion (Rouse & Tsang, 2010). The acquisition of Volvo was preceded by several efforts by Geely to strengthen its technological capabilities and to consolidate as a global firm. In 2006, it established a JV with MB Holdings to produce the 'London taxi' in Shanghai. Geely also acquired Australian Drivetrain Systems International Pty Ltd in 2009 (global.geely.com).

The technology transfer agreement signed between Geely and Volvo in 2012 and the US 11 billion investment in Volvo to build assembling plants in China to produce a range of new cars indicate that Geely is trying to consolidate itself as a global brand (The Economist, 2014). It seems that Volvo, under Geely, is recovering from the Ford Motor years, as sales of the first model launched under the Geely ownership, the XC90, increased to 0.5 million vehicles in China, Sweden and the US, with China as its major market (Sharman, 2015). Geely is also investing in alternative energies, conducting R&D in methanol vehicles and acquiring some patents in this regard. In cooperation with the local government, Geely has been investing in pilots of 150 methanol-fuelled taxis in Guiyang since late April 2015 (global.geely.com).

In 2011, the bankrupt Saab and its UK dealer network was acquired for EUR 100 million by Chinese Pang Da Automobile Trade Corporation (Pang Da) and Zhejiang Youngman Lotus Automobile Corporation (Youngman), along with an estimated investment of EUR 245 million to maintain production in Sweden and to start manufacturing in China (Ruddick, 2011).

Table 1 presents the major ventures of the Chinese passenger vehicle firms, illustrating the active interaction of Chinese auto firms with Western firms. The table also illustrates how the Chinese auto industry is reshaping itself around JVs as the core of its structure (Luthje & Tian, 2015).

Table 1. Major Chinese JVs in the passenger vehicles sector

Chinese company name	Western company JV	Western acquisition
Shanghai Automotive Industry Corporation (SAIC)	VW GM	
China FAW Group Corporation	VW Audi Toyota	
Guangzhou Automobile Group	Toyota Honda	
Dongfeng Motor Company	Honda Nissan	Peugeot SA (Feb. 2014)
China Changan Automobile Group	Ford Mazda	
Beijing Automotive Group (BAIC)	Hyundai Daimler	
Brilliance Auto	BMW	
Zhejiang Geely Holding Group (Geely)		Volvo (2008)
Pang Da Automobile Trade Corporation (Pang Da)		Saab (2011)
Zhejiang Youngman Lotus Automobile Corporation		Saab (2011)
AVIC		Hilite International GmbH (Oct. 2014)

Source: Prepared by the author with information from Evans (2015); Luthje and Tian (2015) and company websites.

In the area of green vehicles, Chinese BYD (a battery manufacturer established in 1995)⁴ and Baoya New Energy Vehicle are important pioneers in the efforts to develop

⁴ BYD acquired Qingchuan Automobile Company in 2003 and started the production of passenger vehicles.

a Chinese electric vehicle (Li, 2015). BYD entered into a partnership with Daimler in 2010 to develop a new electric vehicle for urban China (Rouse & Tsang, 2010).

The influence of national goals and public policy to make China into a competitor to the West is the first underlying difference between the Chinese and the Indian case presented here. As documented by Chu (2011), Chinese industrial policy has been in constant evolution since 1978. Through local experiments and constant changes, the policies have been adjusted towards a common goal: catching up with the West and competing at the level of the North. Through acquisitions of foreign brands, Chinese automotive companies have reached the mass scale needed to become major competitors in the US and European auto markets. Access to public funds is another factor favouring Chinese firms' investment in acquiring global technology and broadening their market presence (Rouse & Tsang, 2010).

The increasing investments by emerging multinationals in Europe have turned the attention of policy-makers and academics towards understanding the insights of this recent trend. The above-mentioned cases illustrate the great differences in motivation and modes of acquisition between different firms in the South. These differences and domestic socio-economic hurdles are the main challenges in incorporating the relationships and dynamics traditionally explored in business literature, as the roots of the interactions differ from those among North and North-South acquisitions. Studies such as the one conducted by Chaminade et al. (2015) are a first step in understanding these dynamics, particularly regarding the learning and innovation patterns brought about under these schemes. As stated by Amighini, Cozza, Giuliani, Rabellotti, and Scalera (2015), there is a great need for empirical studies exploring the internationalisation of technologies by the acquiring firms, as well as their effects on the domestic and host markets.

Trajectory three: Research and innovation towards the search for new markets

Established in 1994, the European Council for Automotive R&D (EUCAR)⁵ is an R&D platform promoting the competitiveness of European automotive industry through strategic collaborative research and innovation (R&I). In the development of roadmaps for innovations targeting an entry into the future market, EUCAR involves all stakeholders of the industry – that is to say, the European Association of Automobile Suppliers (CLEPA), research and technology organisations, universities, SMEs, transport systems and infrastructure, road transport users, national, regional and city governments, technology platforms and public-private partnerships.

The strategic vision of EUCAR is organised around three strategic pillars: (a) sustainable propulsion, (b) safe and integrated mobility and (c) affordability and competitiveness EUCAR (2014b). Research and innovation (R&I) in targeting these technological challenges is done by coordinating common pre-competitive issues of mutual interest among EUCAR⁶ members within the working packages of the Horizon 2020 framework (H2020).⁷ Table 2 presents the main technology targets for the period 2014-2020.

Table 2. Automotive technology targets (2014-2020)

Sustainable propulsion	Safe and integrated mobility	Affordability and competitiveness
Powertrain technologies <i>(ICE-based powertrain; xEV- including BEV, FCEV, REEV and PHEV) based powertrain)</i>	(Road) safety	Materials
Fuels and energy <i>(Lower CO2 and exhaust emissions technology)</i>	Driver-vehicle dialogues	Manufacturing technologies

⁵ Previously the Joint Research Committee (JRC) of the European motor vehicle manufacturers.
⁶ EUCAR represents the 14 major European manufacturers: Volvo Group, Volvo Cars, BMW Group, DAF, Daimler, Ford of Europe, GM/Opel, Porsche, Jaguar Land Rover, PSA Peugeot Citroen, Renault, Volkswagen and Scania.
⁷ The H2020 framework is the largest EU research and innovation program, with over EURO 80 billion of funding available over the period 2014-2020 (European Commission, 2015). H2020 is composed of three complementary program sections, namely excellent science, industrial leadership and societal challenges (<http://ec.europa.eu/programmes/horizon2020>).

Battery electric and fuel cell electric vehicles

Automated vehicles

Virtual engineering

Common off-board data platform
(*Cloud-connected vehicles*)

Fluid vehicle traffic

Source: Prepared by the author with information from EUCAR (2014a; and 2015).

The two main differences between H2020 and the previous seven framework programmes (FP) are: (i) a considerable increase in funding and (ii) an important change in approach, in which the target is to fulfil a societal need through multidisciplinary efforts, and not the search for technological mastery, as in the previous FPs (Montalvo & Leijten, 2015).

The technology targets of the European automobile industry mentioned in the first two columns of Table 2 are included within three of the H2020 Societal Challenges, as seen below.

- (a) Secure, clean and efficient energy, designed to support the transition to a reliable, sustainable and competitive energy system. Based on the 2008 Strategic Energy Technology Plan (European Commission, 2015d), this energy challenge has a budget of EUR 5,931 million (2014-2020), and it is divided into energy efficiency, low carbon technologies and smart cities and communities (European Commission, 2015b).
- (b) Smart, green and integrated transport, which aims to achieve a resource-efficient climate and an environmentally friendly, safe and seamless European transport system. The budget allocated for this challenge is EUR 6,339 million (2014-2020). The proposals for this work programme are: (i) mobility for growth, (ii) green vehicles, which includes the European Green Vehicles Initiative (EGVI), and (iii) small businesses and fast track innovation for transport (European Commission, 2015c). The EGVI involves three European technology platforms, namely ERTRAC, EPoSS and SmartGrids, which focus mainly on the energy efficiency of vehicles and alternative powertrains.
- (c) Climate action, environment, resource efficiency and raw materials. This work programme seeks to increase European competitiveness, enhance raw materials

security and improve livelihood by securing environmental integrity and sustainability through eco-innovation (European Commission, 2015a).

Column three of Table 2 corresponds to the H2020 working package on Industrial Leadership, namely Leadership in Enabling and Industrial Technologies, under the following categories:

- (a) Information and communication technologies.
- (b) Nanotechnologies, advanced materials, advanced manufacturing and processing and biotechnology. This category includes contractual Public Private Partnerships (cPPPs) in three areas, including Factories of the Future (FoF), an area in which the automobile industry has been an important actor under FP7.

The selection of these societal challenges was not random. They were based on a long series of discussions in Brussels in the years before the implementation of H2020. The output of some of these meetings is reflected in reports such as Montalvo, Tang, Mollas-Gallart, Vivarelli, Marsilli, Hoogendorn, Butter, Jansen, and Braun (2006), Montalvo and van der Giessen (2012)'s synthesis report on the Sectoral Innovation Watch (SIW) (2008-2010) and Ploder, Remotti, Vonortas, Soderquist, Spanos, Borelli, Ipektsidis, Montalvo, Vallejo, Lazaro, Kuittinen, Welsum van, Goyal-Rutsaert, and Wamae (2011)'s research and technology development (RTD) sector studies (2010-2011), among other initiatives. At the core of these societal challenges is the increase in environmental and energy regulations implemented in the European Union (EU).⁸ Table 3 presents the vehicle classification and implementation dates of the Euro 5 and Euro 6 norms.

Table 3. Implementation dates of Euro 5 and Euro 6

Standard	Vehicle class	New type approvals	New registrations
Euro 5	M1, M2, N1 Class 1	1 Sept. 2009	1 January 2011
	M1 designed to fulfil specific social needs	1 Sept. 2009	1 January 2012
	N1 classes II and III, N2	1 Sept. 2010	1 January 2012
Euro 6	M1, M2, N1 Class 1	1 Sept. 2014	1 Sept. 2015
	N1 classes II and III,	1 Sept. 2015	1 Sept. 2016

⁸ More on legal regulations of CO2 emissions at the EU can be found at <http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:52014PC0028>.

Source: rsa.ie/information notes (Irish Road Safety Authority, 2015). Note: Vehicle classifications can be found in http://transportpolicy.net/index.php?title=EU:_Vehicle_Definitions.

In achieving the environmental targets, two lines of action are being followed simultaneously by the automobile industry: (i) improvement of existing technologies, for which a market and technological knowledge is existing, and (ii) development of new technologies, in an activity closely related to the creation of new (future) markets.

The reduction of CO₂ emissions remains as the main environmental target. In order to tackle it, the automobile industry has been forced into a technological evolution. Examples of how environmental regulations influence the development and market implementation of clean technologies are given by Quandt (1995) and Yarime, Shiroyama, and Kuroki (2008), who illustrate how the zero emissions vehicles (ZEV) requirements in the US strongly influenced the development of the electric vehicle programmes.

Cohen, Di Minin, Motoyama, and Palmberg (2009) and Magnusson and Berggren (2001) report how the ZEV influenced Toyota's development of its hybrid system's technological capabilities. In a similar trend, authors such as Molot (2008) and Pilkington and Dyerson (2006) point to the increasing creation of research consortia among car manufacturers, such as the one between GM, Daimler and BMW on hybrid technology. Pilkington and Dyerson (2006) highlight the essential role of first-tier suppliers, such as Bosch, Denso, Valeo and Delphi, in pushing fuel-efficient innovations in order to comply with the increasing environmental regulations.

A detailed explanation of the strategic activities carried out by individual firms in developing hybrid-electric engines is presented by Dijk and Yarime (2010), who show how increasing environmental concerns and the costs of fuel forced the co-evolution of producers and users in the case of the market commercialisation of hybrid-electric engines in automobiles in the late 1990s.

It is clear that to meet the environmental requirements, alternative powertrain technologies need to be introduced to the market. In the last decades, there has been a great advance not only in improving existing powertrain technologies, but also in

developing alternatives, such as electric, fuel-cell (FCV), batteries and hybrids. However, these alternatives are not yet viable substitutes for traditional ICE powertrains in economic or performance terms (Brownstone & Train, 1999; Holweg, 2014; Train & Winston, 2007; Walther, Wansart, Kieckhafer, Schnieder, & Spengler, 2010).

Taken from Walther et al. (2010, p. 242), Table 4 presents a scenario with alternative options that the auto industry could adopt to satisfy the established environmental targets.

Table 4. Powertrain alternatives

Option	Detail	Low-carbon innovations
Improve efficiency of conventional powertrain vehicles	(a) Reduce rolling resistance (b) Reduce air resistance (c) Downsize engine	(a) Advanced internal combustion engines (aIEC), based on improved fuel-injection systems, turbo charging, advanced valve management, etc.
Change in fleet composition	(a) Higher share of small vehicles (b) Specific low-consumption vehicles	
Change in fuel/powertrain	(a) Bio-fuels, natural gas (b) Partly electric: hybrid, plug-in hybrid (c) Fully electric: battery, H2 fuel cell	(a) Bio-fuel and flex-fuels vehicles (FFV) (b) Battery electric vehicles (BEV) (c) Fuel cell vehicles (FCV) (d) Hybrid-electric vehicles (HEV) (e) Plug-in hybrid vehicles (PHEV)

Source: Columns one and two from Walther et al. (2010, p. 242). Column three from Penna and Geels (2015).

R&I on technological alternatives (particularly on alternative powertrains) has been conducted by EUCAR and its members through private-public partnerships (PPP), under the FP7⁹. Most of these PPPs are maintained under H2020, such as the Hydrogen & Fuel Cells Joint Undertaking (FCH JU), the EGCI (the predecessor of EGVI under H2020) and Factories of the Future (under the H2020 Industrial Leadership working package). EUCAR (2014a) presents examples of projects financed under the FP7 illustrating the inclusion of research for alternative sources of energy and powertrains in previous EU agendas.

⁹ The 'Seventh Framework Programme for Research and Technological Development' (FP7) lasted from 2007 until 2013 and included a budget of EUR 50 billion.

Under H2020, a minimum budget of EUR 5 billion has been assigned within H2020 Societal Challenges (2015-2020) to activities designed to ensure the continuation of R&I in these areas (EUCAR, 2012).¹⁰ H2020 Societal Challenge: Green Vehicles has allocated EUR 129 million to this task. Table 5 presents the first approved and signed proposals of H2020 under the Green Vehicles challenge.¹¹

Table 5. Signed proposals for H2020-Green Vehicles (2015)

Project Name	Coordinator	Budget (Funding)	Period
Call: Next generation of competitive Li-ion batteries to meet customer expectations (GV-1-2014)			
Five Volt Lithium Ion Batteries with Silicon Anodes produced for Next Generation Electric Vehicles (FIVEVB)	AVL List GmbH (AT), coordinator	EUR 5,927,428.75 (financed: EUR 5,673,272.50)	MAY2015-MAY2018
Silicon and Polyanionic chemistries and architectures of Li-ion cell for high energy battery (SPICY)	Commissariat a l'energie atomique et aux energies alternatives (FR), coordinator	EUR 7,250,428.75 (financed: EUR 6,896,053.50)	MAY2015-MAY2018
Call: Optimised and systemic energy management in electric vehicles (GV-2-2014)			
Optimised and Systematic Energy Management in Electric Vehicles (OSEM-EV)	Infineon Technologies AG (DE), coordinator	EUR 8,002,536.25	JUN2015-JUN2018
Innovative Climate-Control System to Extend Range of Electric Vehicles and Improve Comfort (XERIC)	GVS S.P.A. (IT), coordinator	EUR 4,621,280	JUN2015-JUN2018
Optimised Energy Management and Use (OPTEMUS)	Kompetenzzentrum - Das Virtuelle Fahrzeug, Forschungsgesellschaft MbH (AT), coordinator	EUR 6,390,633.75	JUN2015-MAR2019
Low energy passenger comfort systems based on the JOule and PELtier effects (JOSPEL)	Asociacion de Investigacion de Materiales Plasticos y Conexas (AIMPLAS), coordinator (ES)	EUR 6,668,288	MAY2015-NOV2018
Call: Future natural gas powertrains and components for cars and vans (GV-3-2014)			
Gas-Only internal combustion engines (JOSPEL)	Centro Ricerche FIAT SCPA (IT)	EUR 23,391,977 (financed: EUR 16,704,977.14)	MAY2015-NOV2018
Call: Hybrid light and heavy duty vehicles (GV-4-2014)			
European Competitiveness in Commercial Hybrid and AutoMotive PowertrainS (ECOCHAMPS)	DAF Trucks NV (NL), coordinator. Includes 26 partners including EUCAR, CLEPA, EARPA and members of ERTRAC and EGVIA	EUR 28,585,128.75 (financed: EUR 21,124,805.30)	MAY2015-MAY2018
Call: Electric two-wheelers and new ultra-light vehicle concepts (GV-5-2014)			
Easily distributed Personal Rapld Transit (ESPRIT)	Commissariat a l'energie atomique et aux energies alternatives (FR), coordinator	EUR 7,996,591.25	MAY2015-MAY2018
Range of Electric Solutions for L-category Vehicles (RESOLVE)	Piaggio & C S.P.A. (IT), coordinator	EUR 6,920,277 (financed: EUR 6,844,027)	MAY2015-MAY2018

¹⁰ In the case of FCH JU a matching budget (i.e. EC, industry and research) of EUR 1.33 billion has been allocated for the period 2014-2020.

¹¹ Although not worked out in this section of the paper, there are many other technological initiatives going on within H2020 that affect the automobile industry – for example, the eCall project, embedded within the Societal Challenge/Road Safety. This initiative requires all new vehicles put in the market from April 2018 to be equipped with eCall technology (<http://ec.europa.eu/digital-agenda/en/news/ecall-all-new-cars-april-2018>).

Social innovation and light electric vehicle revolution on streets and environment (Silver Stream)	Infineon Technologies AG (DE), coordinator	EUR 4,573,567.50 (financed: EUR 3,990,111.25)	JUN2015-JUN2018
Ultralight and ultrasafe adaptable 3-wheeler (WEEVIL)	Fundacion Tekniker (ES), coordinator	EUR 6,293,944	JUN2015-JUN2019
Efficient Urban Light Vehicles (EU-LIVE)	Kompetenzzentrum - Das Virtuelle Fahrzeug, Forschungsgesellschaft MbH (AT), coordinator	EUR 6,713,338.75	JUN2015-JUN2018
Call: Future alternative fuel powertrains and components for heavy duty vehicles (GV-7-2014)			
Heavy Duty Gas Engines integrated into Vehicles (HDGAS)	AVL List Gmbh (coordinator). (AT), coordinator	EUR 27,839,421.25 (financed: EUR 19,890,587.50)	MAY2015-MAY2018

Source: European Union Participant Portal

(<http://ec.europa.eu/research/participants/portal/desktop/en/opportunities/h2020/calls/h2020-gv-2014.html>) and European Union Open Data Portal (<https://open-data.europa.eu/en/data/dataset/cordis-h2020projects-under-horizon-2020-2014-2020>). Note: AT=Austria, DE=Germany, ES=Spain, FR=France, IT=Italy, NL=The Netherlands.

As mentioned by Walther et al. (2010), and Penna and Geels (2015), and illustrated in the variety of projects presented in Table 5 there is not yet a clear technological design that can compete in the market with the costs and performance of traditional powertrains.¹² The large variety of alternatives makes it financially impractical for individual firms in the industry to develop and test them all. Therefore, the H2020 framework (as in previous FPs) allows them to work, under the coordination of EUCAR, towards the development of these new technologies and their applications without the need to exclude potentially effective technologies due to a lack of resources. Building on FP7, H2020 allows them not only to continue building the pre-competitive technological capabilities required but also to start pilot production (a characteristic of H2020 that was not present in FP7).

The introduction of Technological Readiness Levels (RTL) requirements added a new dimension to H2020 calls, not only to measure the level of maturity of the technology (within and at the end of the project), but also to specify the scope of the project's activities.

¹² See also EUCAR (2014a) for examples of technological developments under the FP7.

Under the coordination of EUCAR, H2020 became a platform in which the automobile industry is able to work together, under the umbrella of the mobility goal, in the development of diverse pre-competitive technological alternatives.

What is important to understand when talking about the H2020 targets is that the direction is from the societal goals towards the technology, and not the other way around. It is a framework in which, on the one hand, public policy establishes the goals and pushes the transformation (Geels, 2014; Mazzucato et al., 2015; Montalvo & Leijten, 2015). And on the other hand, it allows participants to address existing market barriers and to pilot production in what Montalvo and Leijten (2015, p. 25) called 'funding for the removal of market barriers'. And most importantly, it provides a platform to foster patents regarding the technologies developed.¹³

Discussion

The study shows how three trajectories are being traced simultaneously in a non-competing environment around the world. The dynamic in the industries of the South is one of continuous learning and improvement; however, only a few firms, as the case of India and China prove, have been able to step forward and invest in Northern firms. These cases appear to represent a new international business (IB) model featuring, on the one hand, Southern owners with the funds to acquire a Northern firm without the technological mastery of the North, and on the other hand, Northern firms with technological mastery but in need of financial injections. The learning effects of these trajectories are still unknown, and a new body of IB literature based on case studies is just starting to form.

Two things are different in the trajectories described. First, there is a new European approach to economic growth, in which pre-competitive technological discovery and

¹³ Keeping up in the low carbon technologies race, The UK government, through Innovate UK has allocated GBP 60 million to the development of low-emission propulsion technologies (<https://www.gov.uk/government/news/low-carbon-vehicles-60-million-for-propulsion-technologies>). The initiative aims to strengthen powertrain engineering and low carbon innovation as an opportunity to access new markets and it is coordinated by the Advanced Propulsion Centre UK (APC). In previous rounds, GBP 90 million have already been allocated to projects exploring improvements in internal combustion engines, lightweight powertrain structures, electric machines and power electronics, energy storage and energy management, as well as alternative propulsion systems .

ownership (i.e. through the corresponding patents) are sought as means to achieve the societal challenges that are targeted explicitly in H2020 and supported by the network of EU environmental regulations and clean energy policies. Second, the financial and environmental stimulus towards the development of new industries, such as robotics and those activities within the Factories of the Future working programme (e.g. 3D printing, artificial intelligence, green materials and cleaner energies) have initiated the development of these new sectors, whose outputs are expected to be integrated by the existing ones in the near future.

In other words, Europe is moving towards new forms of joint competition in which not only are industries rising to meet societal challenges but also partnerships are the key element of competition. The competition for FP7 and H2020 grants has brought to Europe the need for intra-regional, intra-sectoral and multi-disciplinary collaboration. Therefore, firms in the automobile industry, for example, are losing their identity as auto manufacturers and resurging as part of the green mobility debate. European economic growth is no longer pursued by promoting individual industries and competing based on costs; rather, the new approach is characterised by competition based on collaborating industries seeking to satisfy societal needs and resulting in the creation of new markets.

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