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Open Innovation in the Automotive Industry: How it affects MNCs' Businesses, collateral impacts and new benchmark definitions

A Case Study between BMW and TOYOTA Hydrogen Fuel Cells technology development

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This work is the product of my curiosity in the automotive sector linked with the invaluable opportunity I had during my academic path at LUISS University to learn the Open Innovation paradigm, presented by Professor Henry Chesbrough (Executive Director of the Center for Open Innovation at the Institute for Business Innovation, University of California, Berkeley) and hosted by my LUISS University Professor Luca Giustiniano in his first-year Master class "Global Design & Human Resource Management".
Since then, I have immediately started real-time contextualizing between Open Innovation theory and the world surrounding me starting from the automotive industry, about which I'm a very enthusiast.
Furthermore, open innovation is recalled in this work because I have researched and analyzed both BMW and TOYOTA characteristics in different countries I have been living in those months. I spent four months in Japan, studying at Hitotsubashi University and working as a research assistant at the HU Institute of Innovation and Research for Professor Ivar Padrón-Hernández. Here I want to do a big thank you to Ken Kusunoki-sensei (Professors and Faculty Member at the Hitotsubashi Business School), Yoshi Fujikawa-sensei (Associate Professor & Faculty in Charge of External Affairs at Hitotsubashi Business School and visiting associate professor at the Yale School of Management), together with the Director of The Institute of Innovation and Research Yaichi Aoshima-sensei for having tried to put me in direct contact with TOYOTA's managers and engineers. Although the company has not accepted my interview proposals, I will always be open to the opportunity to take interviews with them.

I want to do a big thank you to my parents, my father Enzo and my mother Rita for having shaped my life so far. This work is something more than just a research thesis: doing this as the result of where I am now, I am rewarding and redeeming my whole generation's effort and struggle. I am the first one to have achieved a high-level education taking a degree, and this thesis is the goal of my Global Management & Politics Master's Degree, which is the third one for me.

To my grandfather Vinicio, who has always dreamt of seeing me attending one of the best Universities in Italy but who wasn't sure about this after I failed my second high-school year.

"Study, study and study. Only by studying you will achieve freedom. Knowledge is the killer of intellectual slavery."

He only had a fifth-grade education.

TABLE OF CONTENTS

Summary

1. ABSTRACT

Collaborations and partnerships in almost all different industries are typical, often bringing positive effects to the business outcomes of the parties involved. Particularly in the automotive industry, partnerships aim to develop car platforms, engines, and other technical parts to spread and share time and monetary costs: "*horizontal alliances*" [1]. Based on an in-depth empirical analysis delivered through primary sources (interviews), the present research starts from an example of a horizontal alliance, analyzing the development of the TOYOTA SUPRA with BMW Z4's technical components, and will extend its focus on something even more significant about this long-lasting collaboration: the development of hydrogen fuel cell technology.

The Open Innovation paradigm can flawlessly fit this way of conjunctively doing business by creating innovation.

By doing this, an academic contribution will be delivered by approaching unexplored literature or conjugating existing theories of B2C-related businesses into B2B theories (i.e. consumer co-development, B2C lock-in effect).

Behind the already known benefits and reasons for mechanical collaboration, conclusions will try to address the hypothesis that such a collaboration can positively affect business, define a new benchmark in the industry, and create limits on the parties' business.

1.1 INTRODUCTION

BMW & TOYOTA (thereinafter referred to as B&T) are two of the most relevant car manufacturers in the world, thanks to their global market share, brand positioning and innovations brought into the car industry. Since 2013, the two companies have been involved in an ongoing collaboration to develop new car models by sharing mechanical components and improving their market's presence. Additionally, this ongoing collaboration aims at developing hydrogen fuel cells and powertrains that will allow the sale of 100% hydrogen-powered cars.

The first part of the present research starts with the analysis of the most relevant late project, which is the development of the TOYOTA SUPRA (thanks to the sharing of the BMW Z4 components): this first section supports the empirical understanding of the benefit brought by this collaboration to the B&T business in terms of sales, costs, and market share increase. Nonetheless, primary and secondary sources' findings align with the core hypotheses of the present research.

Later, this research will focus on its core section: the link between B&T's know-how to develop hydrogen fuel cell technology. This one-of-a-kind collaboration is the perfect spark for an Open-Innovation-approach analysis in the car industry.

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[1] Willem P. Burgers, Charles W. L. Hill, W. Chan Kim, "***A Theory of Global Strategic Alliances: the Case of the Global Auto Industry***", Strategic Management Journal, Vol. 14, 419-432 (1993)

1.2 MOTIVATION

Particularly between 1990 and 2006, when Hydrogen Technologies (HTs) were incorporated into the automotive sector as a solution to deal with its environmental impact (i.e. atmospheric emissions reductions, fuel consumption, and noise), HTs have drawn much attention from politicians, academics, and the media (Bakker et al., 2009). Despite energy balance analyses consistently demonstrating a poor life cycle energy performance of hydrogen-based mobility, studies on HTs are still on the agenda of businesses, research organisations, and policymakers due to hydrogen's potential in the development of renewable energy storage, energy supply security, and decentralisation of the energy system. However, many unsolved concerns still need to be addressed regarding HTs' technological life cycle. One of these is the "chicken-egg" question of whether a lack of infrastructure impedes alternative vehicles or the other way around (Browne et al., 2012)[2].

As a scholar, the interest behind this research comes from a deep interest in analysing the Open Innovation paradigm in the automotive industry, particularly once aware of the collaboration between B&T circa the development of Hydrogen fuel cell technology and its lack of analysis and literature in the academic context. More specifically, implementing the Open Innovation paradigm helps address the hypotheses about how such an industrial approach can benefit Multinational Corporations (MNCs) in their multinational business and activities: particularly defining a new benchmark in the car industry by gaining a significant competitive advantage if compared to direct competitors.

Moreover, once analysed, this kind of collaboration starts from an academic and managerial perspective; the core motivation comes from a lack of literature in the general B2B context, particularly:

- internationalisation through innovation development, considering the collaboration of teams from two different companies, two countries and, consequently, two distinct cultures (Germany and Japan). Academic literature widely mentions the so-called "co-design in the provider-consumer context", but at the time of writing, there is no existence of something related to the co-design concept in the B2B context. This aspect is what this research will define as "co-design in the provider-provider context";
- partner/third-party strict dependencies: particularly the limit and issue of depending too much on a partner-supplier, who can deliberately decide and change prices and conditions of an ongoing partnership. What is generally called the "Power of suppliers" in 5 Porter's forces will be further explored considering a context of collaboration and cooperation, not just as a pure buyer-supplier relationship.

Power of suppliers is described as ***"****Powerful suppliers (*that) *capture more of the value for themselves by charging higher prices, limiting quality or services, or shifting costs to industry participants. Companies depend on a wide range of different supplier groups for inputs. A supplier group is powerful if:*

- *It is more concentrated than the industry it sells to;*

[2] P. Siskos, P. Capros, "***Restructuring transport sector towards sustainability: infrastructure and market prospects of alternative fuels in EU transportation***", International Journal of Decision Support System Technology, 2015

- *The supplier group does not depend heavily on the industry for its revenues. Suppliers serving many industries will not hesitate to extract maximum profits from each one. If a particular industry accounts for a large portion of a supplier group's volume or profit, however, suppliers will want to protect the industry through reasonable pricing and assist in activities such as R&D and lobbying;*
- ***Industry participants face switching costs in changing suppliers. For example, shifting suppliers is difficult if companies have invested heavily in specialized ancillary equipment or in learning how to operate a supplier's equipment;***
- *[…]"*[3]

The case of B&T becomes an academic case study of a collaboration to develop an innovative and advanced outcome (Fuel cells), joining the two know-hows (both B&T's know-how is then in every single fuel cell), but the physical production is under TOYOTA, making BMW its customer and bargaining fuel cells' price. Once again, academic literature mentions similar concepts only in the B2C context, named "*business-to-consumer lock-in effect*" by M. Eurich and M. Burtscher (2014) [4]. As will be illustrated in the reflection section, the present research will try to explore and expand the academic literature by defining this phenomenon as a "*business-to-business lock-in effect.*"

1.3 RESEARCH QUESTION

The present research thesis wants to address the following research questions: *is the development of hydrogen technologies between B&T the result of an Open Innovation approach? How does Open Innovation affect strategic business and management decisions? Are there any limits or opposing sides in these strict and effective collaborations?*

1.4 HYPOTHESES PRESUPPOSITION

A necessary clarification must be made: the interest in such research started at the end of 2021. At that time, the European political environment was particularly sensitive to the so-called "green transaction", but nothing was about regulative imposition toward car manufacturers (apart from producing combustion cars above defined polluting limit. After the core hypotheses have been defined during that period (November 2021), on Jun 29 2022, the EU approved an agreement that officially stops the sale of combustion cars which will enter into force starting from Dec 31 2035. The state-of-the-art (September 2022) is represented by Germany as the pioneer European country, counting more than 97 available Hydrogen refuelling stations, having the whole of Europe counting 176 [5].

[3] Michael E. Porter, "T***he Five Competitive Forces That Shape Strategy***", Harvard Business Review, 2005
[4] M. Eurich, M. Burtscher, "***The Business-to-Consumer Lock-in Effect",*** University of Cambridge, August 2014
[5] https://www.clean-hydrogen.europa.eu/get-involved/european-hydrogen-refuelling-station-availability-system_en

1.5 CORE HYPHOTESES

In order to answer the research questions, three hypotheses has been formulated:

The first hypothesis (H1) is that the debated collaboration between BMW and TOYOTA for the TOYOTA Supra development has been a sort of "do ut des" Open Innovation strategy to finally embrace Open Innovation in a long-lasting collaboration for the development of Hydrogen Fuel cells. Particularly, supporting the idea that BMW may have used its delivered car parts as a "bargaining chip" to gain fuel cell know-how later.

The second hypothesis (H2) lies in the belief that considering the harsh Japanese policies regarding foreign car brands in the Japanese market, BMW could have gained chances to increase its presence (in terms of market share) in Japan.

The third hypothesis (H3) is that, thanks to the Open Innovation strategic approach, BMW and TOYOTA could have defined a new benchmark in the car industry regarding the Hydrogen fuel cell technology they have been developing together. More precisely, H3 lies in the idea that Open Innovation is definitively essential to create competitive advantage, gaining market share, and strengthen-up market presence.
Moreover, in line with the hypothesis presupposition (EU ban on ICEs starting from 2035), BMW could become a new benchmark in the European car industry in regard with its direct competitors (Audi and Mercedes-Benz), thanks to an Open Innovation approach.

2. CONCEPTUAL FOUNDATIONS: THE OPEN INNOVATION PARADIGM (H. CHESBROUGH)

The present research work has its conceptual foundations in the paradigm of Open Innovation (OI), a theoretical model coined and developed by the PhD. Henry Chesbrough: this paradigm aims to create innovation thanks to the company's open boundaries instead of "closed innovation".

As Chesbrough (2003) states*, Open innovation* is a paradigm that encourages companies to look beyond their internal R&D efforts and actively seek external ideas, technologies, and resources to enhance their innovation performance [6]. This concept, first introduced by Henry Chesbrough in 2003, is based on the idea that organizations can and should use external knowledge and expertise to supplement their internal capabilities to achieve better results than they could by relying solely on their internal resources.

"*If you want something done right, you've got to do it yourself*".[7]

The OI paradigm is based on the notion that companies can no longer rely solely on internal R&D to generate new ideas and technologies. In today's rapidly changing business environment, companies must be more agile and responsive to new market demand conditions and leverage external knowledge and expertise to stay competitive (H. Chesbrough, 2003). By leveraging external resources, companies can reduce the time and costs associated with R&D and access new markets and technologies that they might not have been able to access otherwise (H. Chesbrough, 2003)[8].

"*Open Innovation is the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively. Open Innovation is a paradigm that assumes that firms can and should use external and internal ideas, and internal and external paths to market, as they look to advance their technology*" [9].

One of the key benefits of OI is that it allows companies to tap into a wider pool of knowledge and expertise. By collaborating with external partners, such as universities, research institutions, and other companies, companies can access new ideas and technologies that they might not have been able to access otherwise. This

[6] H. Chesbrough, "***Open innovation: The new imperative for creating and profiting from technology***", Harvard Business Press, 2003

[7] H. Chesbrough,"***Top 10 Lessons on the New Business of Innovation***", MIT Sloan Review, Winter 2011 Edition

[8] H. Chesbrough, "***Open innovation: The new imperative for creating and profiting from technology***", Harvard Business Press, 2003

[9] H. Chesbrough, "***Open Innovation: A New Paradigm for Understanding Industrial Innovation***", Academia, 26th October 2005

can help companies to stay ahead of the curve in terms of innovation, and it can help them to stay competitive in a rapidly changing business environment.
Another benefit of OI is that it can help companies to reduce the risks associated with R&D by collaborating with external partners, allowing companies to share all the risks associated with it while helping to mitigate the potential negative consequences of failure.
OI makes companies more agile and responsive to changing market conditions. By leveraging external resources, companies can be more flexible in their R&D efforts and quickly pivot in response to changing market conditions.

As of July 2022, the existing literature has yet to explore any aspect of collaboration in the automotive industry regarding the development of hydrogen fuel cells, particularly approaching the Open Innovation paradigm.

This paradigm is appropriate for the collaboration between B&T, two automotive MNCs, and, to support this, it is of fundamental importance to mention Gassmann (2006) when he argues that "*the more an industry's idiosyncrasies correspond to developments and trends like (1) globalization, (2) technology intensity, (3) technology fusion, (4) new business models and (5) knowledge leveraging, the more appropriate the Open Innovation model seems to be.*"[10]
Furthermore, "*Open innovation starts with simple outsourcing deals with contract service organizations to reduce overcapacities, cut costs, grow through complementary assets or reduce risks*"[11].
Graphically, this paradigm must be imagined as a perforated funnel which allows information flow to go inside-out and outside-in, allowing reciprocal exchange in terms of know-how first.

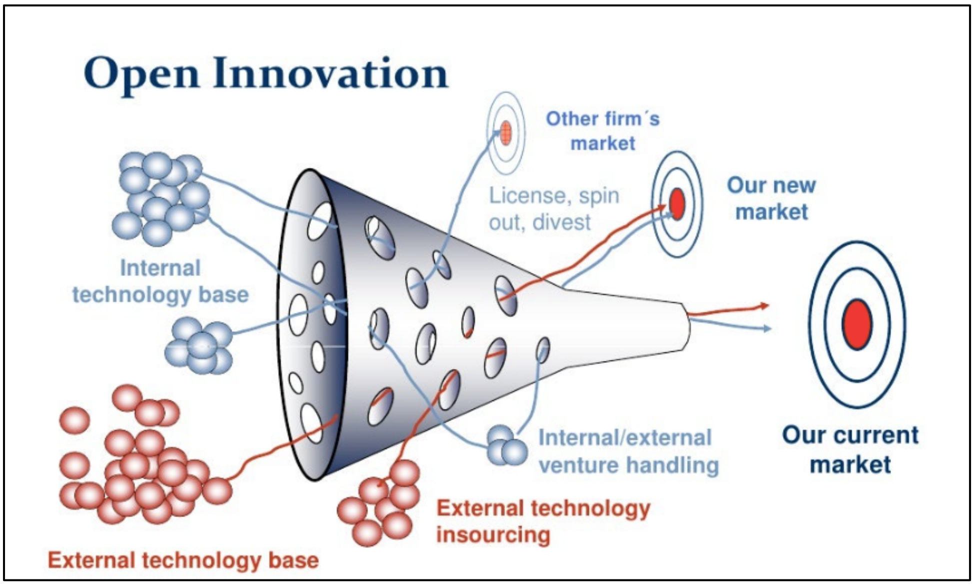

Fig. 1: Source: Prof. Henry Chesbrough UC Berkeley, Open Innovation: Renewing Growth from Industrial R&D, 10th Annual Innovation Convergence, Minneapolis Sept 27, 2004

[10] S. Ili, A. Albers, S. Miller, "***Open innovation in the automotive industry***", R&D Management, 7 May 2010
[11] O. Gassmann, E. Enkel, H. Chesbrough, "***The future of Open Innovation",*** R&D Management, June 2010, p. 213-221

The funnel concept in the OI paradigm refers to identifying and evaluating potential external ideas or technologies that can be integrated into a company's product or service offerings. It begins with many potential external sources, such as customers, suppliers, and research institutions. It gradually narrows down to a smaller set of ideas or technologies that have been thoroughly evaluated and are deemed most promising for further development and commercialization[12].

According to Chesbrough (2003), "*the funnel is a way of thinking about the stages through which an organization filters and develops external ideas and technologies. It visually represents the steps involved in identifying, evaluating, and selecting external ideas and technologies that can be integrated into the organization's product or service offerings*."

[12] H. Chesbrough, "***Open business models: How to thrive in the new innovation landscape***" Harvard Business Press, 2006

3. CASE STUDY

3.1 THE BMW Z4 AND TOYOTA SUPRA DEVELOPMENT: AN EXAMPLE OF HORIZONTAL INTEGRATION

The present Open Innovation research between B&T starts from a case of horizontal alliance circa the design and development of the TOYOTA SUPRA (the model year 2019, the restyling of the historical Supra model, 1978) thanks to technical components given by BMW from its Z4 (BMW model year 2019).

The BMW Z4 and the Toyota Supra are two sports cars jointly developed by the German automaker BMW and the Japanese automaker Toyota. This collaboration was announced in 2011 to jointly develop a new sports car platform and a new sports car model, and this partnership allowed the companies to share the costs and risks associated with developing a new sports car platform and bring the new car to market more quickly[13].

The BMW Z4 and the Toyota Supra share many design, performance, and technology similarities. For example, both cars are based on the same platform, a rear-wheel drive platform that BMW and Toyota jointly developed[14]: it allows for a low centre of gravity, which improves handling and stability. Both cars are powered by a 3.0-litre turbocharged inline-six engine that produces around 335 horsepower and 365 lb-ft of torque and, additionally, both cars feature similar suspension and braking systems, which provide excellent handling and braking performance.

The BMW Z4 and the Toyota Supra also share many similarities in terms of technology. Both cars feature an eight-speed automatic transmission and rear-wheel drive, and both cars come with various advanced driver assistance systems (ADAS), such as lane departure warning, forward collision warning, and automatic emergency braking.

One of the main advantages of this collaboration is the cost savings that BMW and Toyota achieved by sharing the development costs of the new sports car platform. According to (Wang et al., 2019), this collaboration allowed the companies to reduce their development costs by up to 20%[15]. This collaboration also allowed BMW and Toyota to share the risks associated with developing a new sports car platform. By sharing these risks, the companies could mitigate the potential financial losses they might have incurred if they had developed the platform independently.

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[13] "BMW and Toyota team up to develop sports car" (2016): https://www.autonews.com/article/20160912/OEM05/309129954/bmw-toyota-team-up-to-develop-sports-car

[14] "BMW Z4 and Toyota Supra: Born to be brothers" (2019): https://www.cnet.com/roadshow/news/bmw-z4-toyota-supra-born-to-be-brothers/

[15] Wang, X., Li, Y., & Wang, X., "***Joint development of new products in the automotive industry: A review***". Journal of Engineering and Technology Management, 51, 1-15, 2019

Fig. 2: TOYOTA Supra (Left) and BMW Z4 (Right) dashboard

3.2 HYDROGEN AS TRANSPORTATION FUEL

Hydrogen is a versatile energy carrier that has the potential to play a significant role in the transportation sector. Hydrogen fuel cell vehicles (FCVs) convert the chemical energy of hydrogen into electricity, which can then be used to fuel electric motors: as a matter of fact, FCVs offer several benefits over traditional gasoline-powered vehicles, including increased efficiency, lower emissions, and reduced dependence on fossil fuels.

One of the main benefits of hydrogen, for example, is increased efficiency: as a matter of fact, FCVs can convert a much higher percentage of the energy in hydrogen into useful work compared to internal combustion engines (ICEs), which are only about 20-25% efficient (J. L. Silveira, L. B. Braga et al., 2009)[16]. On the other hands, FCVs are able to convert up to 60% of the energy in hydrogen into useful work, which means that they can travel farther on the same amount of fuel (K. Agbossou et al., 2004) [17]. This can help to reduce the overall cost of transportation, as well as reduce the need for refueling.

Another benefit of hydrogen is reduced emissions: FCVs produce no tailpipe emissions, as the only by-product of the fuel cell reaction is water vapor. This is in contrast to ICEs, which produce a variety of pollutants, including carbon monoxide, nitrogen oxides, and particulate matter. By reducing emissions, as evidenced in K. Riahi and A. Roehrl's research, (2017) hydrogen transportation can help to improve air quality and mitigate the effects of climate change[18].

[16] J. L. Silveira, L. B. Braga a, A. C. Caetano de Souza, J. S. Antunes, R. Zanzi, "***The benefits of ethanol use for hydrogen production in urban transportation***", Renewable and Sustainable Energy Reviews, Volume 13, December 2009, Pages 2525-2534

[17] K. Agbossou, M. Kolhe; J. Hamelin; T.K. Bose, "***Performance of a stand-alone renewable energy system based on energy storage as hydrogen***", IEEE Transactions on Energy Conversion, Vol. 19, September 2004

[18] K. Riahi, A. Roehrl, "***Energy pathways for sustainable mobility***", Nature Energy, 2(2), 17111, 2017

Large-scale use of Hydrogen can also help reduce dependence on fossil fuels: hydrogen can be produced from various sources, including natural gas, water and other renewable energy. This means that hydrogen can be used as a transportation fuel even in places where fossil fuels are not readily available; in addition, it can be produced using renewable energy sources such as solar, wind, and hydro power, which means that hydrogen has the potential to be completely emissions-free (F. Dawood, M. Anda, G.M. Shafiullah, 2020)[19].

3.3 HYDROGEN FUEL CELL: WHAT IS IT

Fuel cells are a type of energy conversion device that can convert the chemical energy of a fuel into electrical energy. They are similar in many ways to batteries, but unlike batteries, fuel cells do not run down or require recharging. Instead, they produce electricity as long as a fuel source is supplied. This makes fuel cells an attractive option for various applications, including transportation, portable power, and stationary power generation.

There are various types of fuel cells, but the most common type is the polymer electrolyte membrane (PEM) fuel cell. PEM fuel cells are also known as "proton exchange membrane fuel cells", which use hydrogen as the fuel and oxygen from the air as the oxidant.

A PEM fuel cell comprises several layers of materials sandwiched together to form a stack. The layers include an anode, a cathode, and a polymer electrolyte membrane: the anode and cathode are typically made of a porous carbon material coated with a catalyst, such as platinum[20].

The polymer electrolyte membrane is a thin sheet of plastic coated with a proton-conducting material [21].

When hydrogen is supplied to the anode of a PEM fuel cell, the catalyst on the anode causes the hydrogen to be split into protons and electrons: the protons can pass through the polymer electrolyte membrane to the cathode, but the electrons don't; instead, the electrons flow through an external circuit, creating an electrical current. At the same time, oxygen from the air is supplied to the cathode, where it reacts with the protons and electrons to form water vapour.

One of the key advantages of PEM fuel cells is that they can operate at relatively low temperatures, typically around 80°C. This makes them well-suited for transportation applications, where the fuel cell can power an electric vehicle. PEM fuel cells are also relatively small and lightweight, which makes them suitable for portable power applications[22].

However, PEM fuel cells also have some limitations. One of the main challenges is that the platinum catalyst is expensive, which makes it difficult to produce PEM fuel cells at a low cost.

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[19] F. Dawood, M. Anda, G.M. Shafiullah, "***Hydrogen production for energy: an overview***", International Journal of Hydrogen Energy, 2020

[20] Wang, X., & Peng, F., "***Polymer electrolyte membrane fuel cell technology: Progress, challenges, and future directions***", Energy & Environmental Science, 8(3), 603-622, 2015

[21] Kim, G. T., & Lee, J., "***Proton exchange membrane fuel cells***" Journal of Power Sources, 307, 1-22, 2016

[22] O'Hayre, R., & Colella, W., "***Fuel cell fundamentals***", John Wiley & Sons, 2015

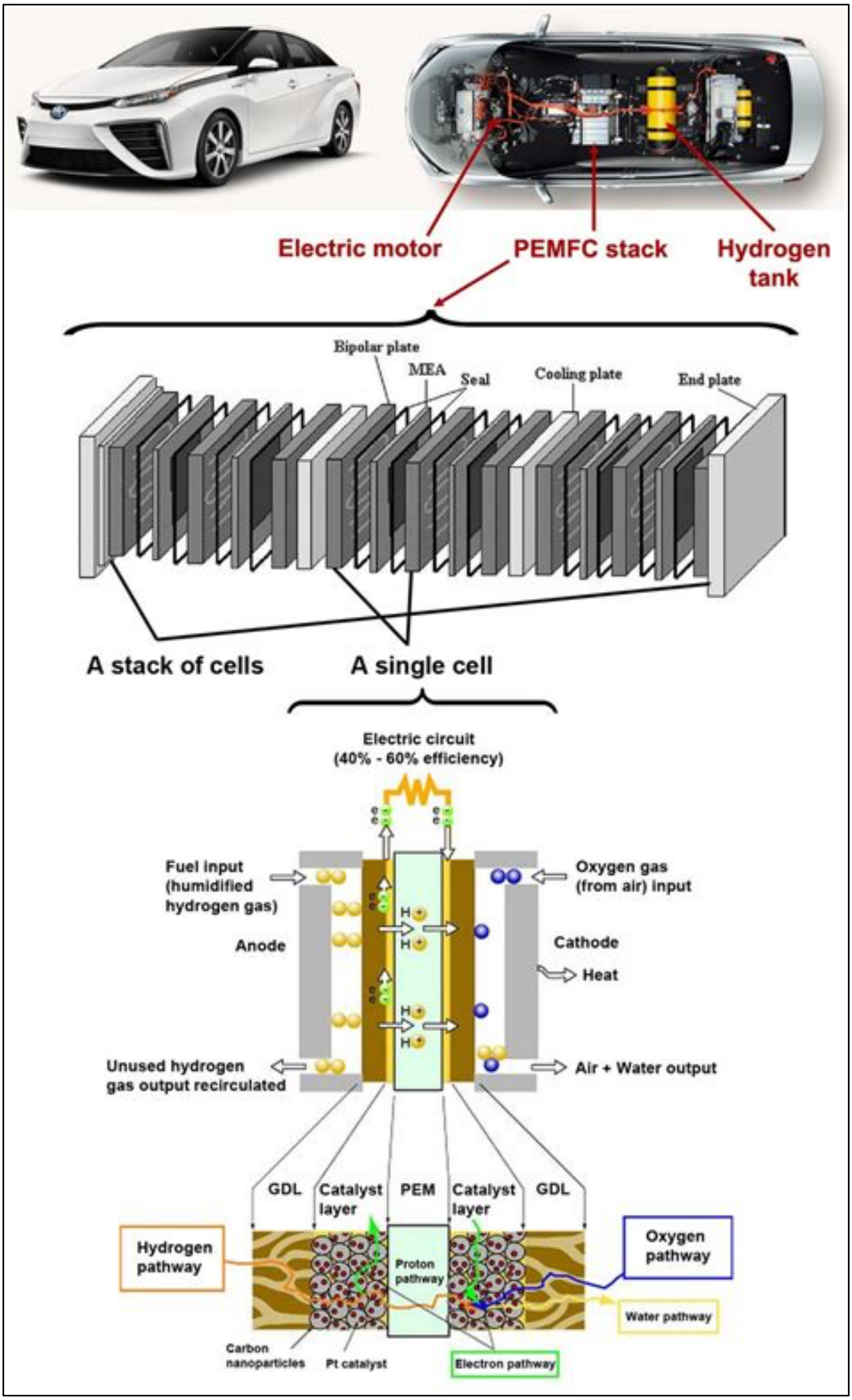

Fig. 3: PEM Fuel Cell exploded view. Source: TOYOTA, 2009

“Fuel cell is any of a class of devices that convert the chemical energy of a fuel directly into electricity by electrochemical reactions. A fuel cell resembles a battery in many respects, but it can supply electrical energy over a much longer period of time. This is because a fuel cell is continuously supplied with fuel and air (or oxygen) from an external source, whereas a battery contains only a limited amount of fuel material and oxidant that are depleted with use.” [23]

3.4 HYDROGEN FUEL CELL: HOW DOES IT WORK

The energy production in a PEM FC starts from hydrogen gas as a supplied fuel: it enters the fuel cell and is provided to the anode or negative side of the fuel cell. Here, an anode catalyst activates the hydrogen molecules and releases electrons thanks to a chemical reaction: those electrons then travel from the anode to the cathode, generating an electrical current. The hydrogen molecules are responsible for releasing electrons to become hydrogen ions. These ions move to the cathode side of the FC, but they still have to go through the polymer electrolyte membrane, which is a porous membrane that allows protons to pass through it. During that process, hydrogen molecules bond with electrons, and the oxygen enters the fuel cell from the atmosphere via the cathode to form water.. During that process, hydrogen molecules bond with electrons, and the oxygen enters the fuel cell from the atmosphere via the cathode to form water.

Typically, the catalyst is made of platinum particles which facilitate the chemical reaction.

As a final step, electricity produced by the fuel cell is supplied to an electric motor that directly powers the vehicle's electric powertrain, or the energy in excess is stocked in a secondary battery that provides supporting power to the powertrain. The final energy storage is only possible if the vehicle’s power scheme is equipped with additional batteries.

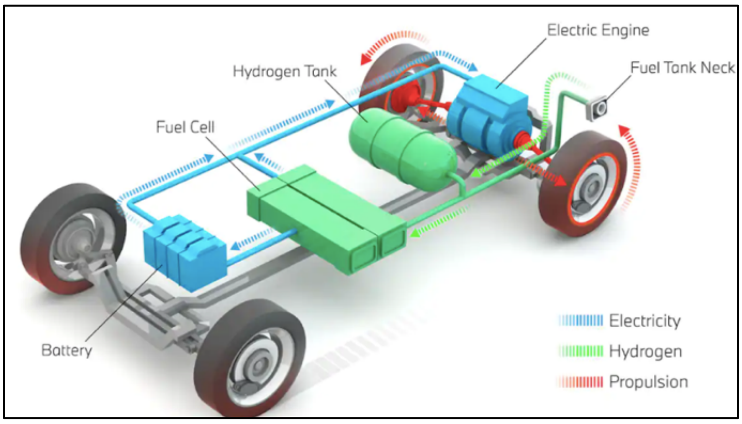

Fig. 4: FCV’s power scheme. Source: BMW, 2021

[23] B. Schumm, ***“Fuel Cell”***, Encyclopaedia Britannica, 27 April 2006

3.5 HYDROGEN AS TRANSPORTATION FUEL: BMW AND TOYOTA'S R&D HISTORY

After the Second World War, a big crisis happened: the 1973 oil. In this scenario, the world was slowly waking up from the nightmare of potential life without petroleum products and, particularly, the transportation industry (C. Issawi, 2015) [24]. During this crisis scenario, BMW was one of the first transport-related manufacturers to get serious about replacing 'gas' – the North American petrol - with natural gas (H2). For their research and development work, the Bavarian luxury carmaker collaborated in 1979 with the German Center for Air & Space Travel (Deutsches Zentrum für Luft und Raumfahrt; DLR). For containing the super cold liquid H2, Messer Griesheim GmbH [Ltd] assisted with developing and fabricating cryogenic tanks. One of the 5-series cars was fitted with tanks for both petroleum and hydrogen fuels and was named '520H'.[25] Immediately after the 5-series production, the 7-series powered by hydrogen was presented in New York in 2000 (called BMW 750 hL, Fig. 5, left). Currently, BMW is planning to sell its first mass-market-oriented car starting from 2023, and it will be the BMW iX5 (Fig. 5, right).

Fig. 5: (left) BMW 750 hL, year 2000 - (right) BMW iX5, year 2022

On the other hand, Toyota's FCV development started in 1992 with the first so-called Fuel Cell Hybrid Vehicle (FCHV), which was first released in 2002 (named FCHV-1, Fig. 6) and was based on the Toyota Highlander. But, in respect of BMW, TOYOTA is still the first automaker in the world to sell an FCV in the consumer market: due to its belief in Hydrogen as a leading energy carrier, it started selling its first consumer-oriented FCV in 2014, namely the TOYOTA MIRAI, then restyled in 2022 (Fig. 7).

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[24] C. Issawi, "***The 1973 Oil Crisis and After***", Journal of Post Keynesian Economics, 4 November 2015
[25] G. Wand, "***BMW using Hydrogen Fuel during Hydrogen & Fuel Cell History***", Hydrogen Cars Now, April 2017

Fig. 6: Toyota FCHV-1 (1997) based on the TOYOTA Highlander

Fig. 7: TOYOTA MIRAI 2014 (left) and 2022 (right)

During its R&D decades, TOYOTA has dramatically improved Fuel Cells' technical specs and addressed three of the main issues:

- **Range**: the cruising range was increased to more than 500 km;
- **Working temperatures**: cold start was enabled from – 30°C;
- **Refuelling times**: lowered to about 3 minutes (more than ten initially)

All of this is possible, and it depends on the Fuel Cells' density: the higher the density, the more efficient the electrical use [26].

Measured evidence of Fuel Cells' improvement is shown in Fig. 8, particularly demonstrating the relation between FC's density and performances. In fact, "*the current density of the MIRAI fuel cell is 2.4 times larger compared to the 2008 model* (Fig. 8). *This improvement enabled the downsizing of the cell and less usage of expensive materials, resulting in significant cost reduction.*" [27]

[26] K. Kojima and S. Sekine, "***Development Trends and Scenario for Fuel Cell Vehicles***," TOYOTA Technical Review, **57**(2), 39 (2011).
[27] T. Yoshida and K. Kojima**, "*Toyota MIRAI Fuel Cell Vehicle and Progress Toward a Future Hydrogen Society*",** *Electrochem. Soc. Interface,* 24-45, 2015

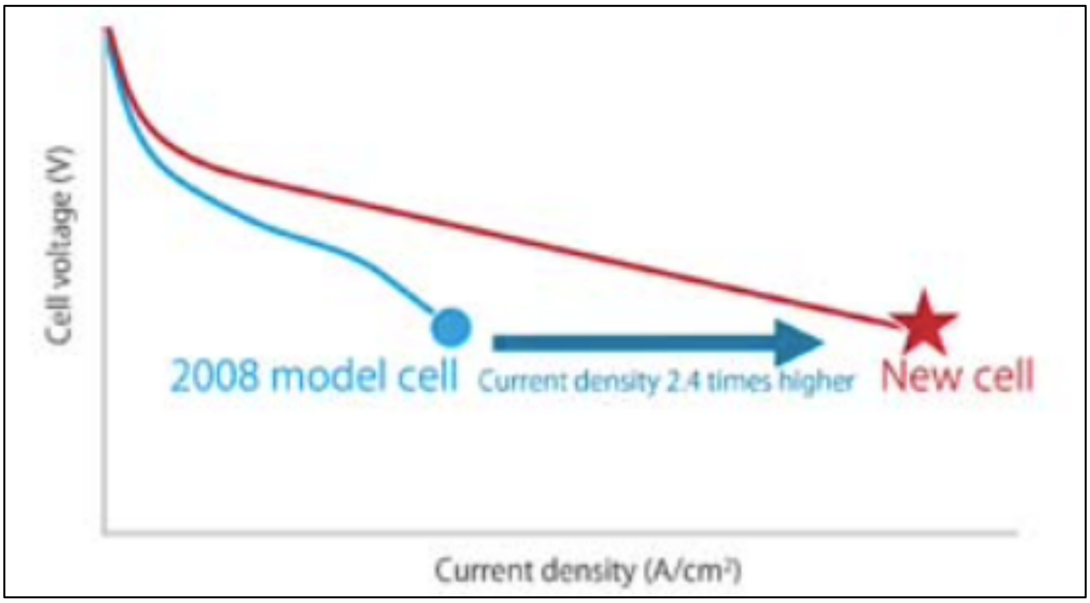


Fig. 8: Current-Voltage curve of 2008 model and MIRAI[28]

4 FINDINGS

4.1 INTERVIEW WITH MR. AXEL RUECKER: PROGRAM MANAGER HYDROGEN FUEL CELL BMW

Despite the non-availability from the TOYOTA side, primary source collection has been possible thanks to the availability of BMW: Mr Axel Ruecker, Program Manager Hydrogen Fuel Cell at BMW, immediately opened up to take the interview on the present research's topic. During his development-related role at BMW, Mr Ruecker has been directly involved in managing the cross-cultural team of BMW and TOYOTA, working together as two engineering teams.
After having presented the core topic of the research, Mr Ruecker was told the research questions, core hypotheses and the main goal of the research itself.

Paragraph 1.3 shows the three main research questions: *"is the development of hydrogen technologies between B&T the result of an Open Innovation approach? How does Open Innovation affect strategic business and management decisions? Are there any limits or opposing sides in these strict and effective collaborations?"*

The interviews positively addressed the presented questions, not only confirming the initial hypothesis but deepening the starting points of the research itself.

Firstly, the collaboration between BMW and TOYOTA in developing Hydrogen Fuel cells definitively results from an Open Innovation managerial approach. Moreover, the interview confirmed the *do ut des* hypothesis

[28] T. Yoshida and K. Kojima, ***"Toyota MIRAI Fuel Cell Vehicle and Progress Toward a Future Hydrogen Society"***, *Electrochem. Soc. Interface,* 24-45, 2015

of giving TOYOTA crucial Supra's components in exchange for gaining significant know-how and business benefits under the hydrogen viewpoint. This first hypothesis is confirmed not only by the interview itself but is supported by data reported in paragraph 4.2: as it will be shown, BMW's increase in Japanese market share was possible *also* thanks to the collaboration with TOYOTA because "*now, in Japan, BMW is seen as a partner of TOYOTA*" (Ruecker, 2022).

H1 and *H2* are confirmed.

For what concerns the hypothesis of BMW becoming a new benchmark in the EU Automotive industry compared to its direct competitors, the interview's findings partially confirm *H3*: in fact, Mercedes Benz is developing in-house FC technology for its trucks (BMW does not have a truck market) and its long-term strategy, when Light Vehicles (LVs) will become relevant in the market, is about scale down their technology to their car segments. *H3* is considered partially confirmed because the initial hypothesis was about BMW having a unique competitive advantage: with this Open Innovation approach, delivered together with TOYOTA, BMW gained a significant competitive advantage, even if it's not 100% unique.

"*We see a big change in the market that will take place in the next 5-10 years, and truck driving will be based on HFCV. Daimler and Volkswagen, for example, are pushing a lot in trucks. Then, if a market for a passenger car is developing, it is easy for these companies (BMW's competitors) to downscale the FC technology they have developed for trucks into passenger vehicles, getting quickly to the market. If this happens, being BMW without a truck market, we could still get competitive with those companies thanks to the ongoing collaboration with TOYOTA. So, if the HFCV market takes speed, the collaboration will help a lot"*. (Ruecker, 2022)

Eventually, *H3* is confirmed.

The abovementioned finding also partially answers the second research question by contextualising an Open Innovation approach and the respective companies' business benefits.

At the same time, primary source findings highlighted some collateral effects of such a collaboration: this has been defined by Ruecker as an *asymmetric collaboration* (2022) due to the unbalanced benefits gained in terms of production expertise of the fuel cells and the consequent third-party dependencies: this very aspect is analysed in paragraph 5.3, by considering a lack in academic literature regarding dependencies in B2B.

Eventually, the invaluable two interviews allowed a further in-depth analysis regarding the Open Innovation approach in terms of cross-cultural teamwork, considering the social and professional benefits gained along this "*Innovation through internationalisation*" (Paragraph 5.2).

4.2 JAPANESE CAR MARKET SALES AND BMW'S MARKET SHARE INCREASE: NUMBERS

The automotive industry in Japan has long been known for its closed market, which refers to the protectionist policies and regulations implemented to limit the import of foreign vehicles and promote the domestic production of cars (D. Gerwin, 1998).

One of the key reasons for Japan's closed market in the automotive industry is the country's history of protectionist policies: Japan has a long tradition of protecting its domestic industries from foreign competition, and the automotive industry has been no exception. This has been done through various measures, including tariffs, quotas, and non-tariff barriers such as regulations and standards that make it difficult for foreign car manufacturers to enter the Japanese market. [29]

The closed market in the automotive industry in Japan has had several effects on the industry: one of the most notable is the dominance of domestic manufacturers in the domestic market. Because foreign vehicles are heavily restricted, domestic manufacturers such as Toyota, Honda, and Nissan have captured a large market share: this has allowed them to invest in research and development and build a strong domestic supply chain, further reinforcing their position in the market while keeping foreign brands limited in their Japanese market share increase. [30] As a matter of fact, Japanese car manufacturers represent the 93.16% of the total Japanese national market share [31]. Those data are represented by the following brands and their respective (%) market share in the year 2021 (based on total sales: 4.448.340):

Japanese car brands performances in Japan - 2021		
BRAND	**SOLD UNITS (2021)**	**% MARKET SHARE (2021)**
TOYOTA	1.424.380	32.02%
SUZUKI	608.379	13.67%
HONDA	579.771	13.03%
DAIHATSU	572.401	12.86%
NISSAN	451.671	10.15%
MAZDA	157.311	3.53%
SUBARU	101.312	2.27%
MITSUBISHI	77.674	1.74%
ISUZU	63.061	1.41%
HINO	60.010	1.34%
LEXUS	51.118	1.14%
FOREIGN BRANDS	301.252	**6.84%**

Table 1 – Source: ***"2021 (Full Year) Japan: Best-Selling Car Brands and Market Analysis",*** Car Sales Statistics, 11th January 2022

[29] D. Gerwin, "***The Automobile Industry in Japan***" Westport, 1998

[30] Porter, M., "***Clusters and the New Economics of Competition***" Harvard Business Review, 76(6), 77-90, 1998

[31] ***"2021 (Full Year) Japan: Best-Selling Car Brands and Market Analysis",*** Car Sales Statistics, 11th January 2022

YEAR	Units BMW	Units AUDI	Units MERCEDES	Units LEXUS	% BMW	% AUDI	% MERCEDES	% LEXUS	Total sold
2012	41.102	24.163	41.911	43.657	0.76%	0.45%	0.78%	0.81%	5,369,720
2013	46.037	28.676	53.731	46.772	0.85%	0.53%	0.99%	0.87%	5,375,513
2014	45.645	31.413	60.839	44.246	0.82%	0.56%	1.09%	0.79%	5,562,887
2015	46.229	29.414	65.162	48.231	0.91%	0.58%	1.29%	0.95%	5,046,511
2016	50.571	28.502	67.386	52.151	1.01%	0.57%	1.35%	1.05%	4,970,260
2017	52.527	28.336	68.221	45.605	1.00%	0.54%	1.30%	0.87%	5,234,166
2018	50.982	26.473	67.554	55.096	0.97%	0.50%	1.28%	1.04%	5,272,067
2019	46.814	24.222	66.553	62.394	0.90%	0.46%	1.28%	1.20%	5,195,216
2020	35.712	22.304	57.041	49.059	0.77%	0.48%	1.24%	1.06%	4,598,615
2021	35.905	22.535	51.772	51.118	0.80%	0.50%	1.16%	1.15%	4,448,340

Table 2 – Source: ***2021 (Full Year) Japan: Best-Selling Car Brands and Market Analysis",*** Car Sales Statistics, 11th January 2022

Graphics 1 shows the percentage (%) of market share in the Japanese market gained by the brands chosen for the comparison (Audi, BMW, Mercedes-Benz and Lexus) in the year 2021.

The comparison here is made between the three leading German competitor brands (most direct rivals), with the presence of the premium brand in the Japanese market (Lexus) as a benchmark.

As the interview's findings suggest, BMW has gained a relevant % of market share in the period between 2013 (the beginning of the collaboration with TOYOTA) and 2021, *also* thanks to the ongoing partnership with the Japanese brand TOYOTA. [32]

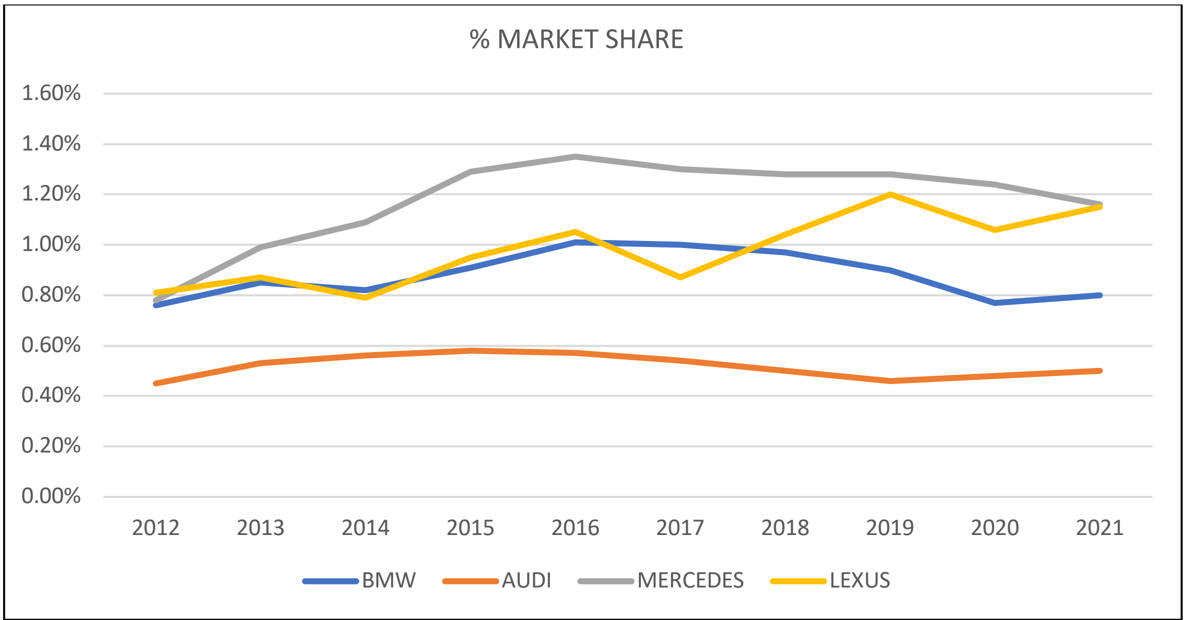
"*Since the beginning of our collaboration, BMW is now seen in Japan as a partner of TOYOTA, which has inevitably improved its image toward Japanese consumers. Furthermore, we can say that the collaboration is one of the factors that allowed BMW's increase in Japanese market share."* (Rucker, 2022)

First, a competitive panorama analysis has to be made to support the hypothesis and address one of the research questions (*how does - Open Innovation - affect companies' success in the industry?*). Japan is claimed as a very closed market to foreign automakers, also thanks to "*unfair trade practices and non-tariff barriers*" [33]. Despite BMW being commonly considered a direct competitor of Mercedes-Benz (it partially is), their positioning is very different: BMW has a market positioning of sporty cars in the premium background; meanwhile, Mercedes-Benz has a brand positioning of pure premium cars and, as a matter of fact, it directly competes with Lexus (which is Toyota's luxury brand). Ceteris paribus (market and external environment) Mercedes-Benz is not considered as BMW's direct competitor, nor is its business performance in the Japanese market.

[32] Interview to Mr. Axel Ruecker, **Program Manager Hydrogen Fuel Cell at BMW**, 23rd May 2022

[33] M. Kahl, "***Japan's 'closed' vehicle market: open for business?"***, Automotive World est.1992, 7th November 2019

Instead, BMW's main and direct German competitor is AUDI.
As it is possible to note from Graphic 1, during the period 2013-2021, BMW has gained a significant market share in the Japanese market, following the increasing trend of sales in Japan but, at the same time, keeping a significant gap with AUDI and, in doing this, showing a higher increase curve. The trend gained by BMW, Audi and Mercedes is quite consistent over the year, both in increse and decrease. Of course, the collaboration between BMW and TOYOTA it's not the only reason for BMW performances in Japan. However, it is a supporting element for confirming the initial hypotesis 2 (*H2*), thanks to the primary sources findings.



Graphic 1: Japanese market share of Audi, BMW, Mercedes-Benz, and Lexus in 2021.
Source: ***"2021 (Full Year) Japan: Best-Selling Car Brands and Market Analysis",*** Car Sales Statistics, 11th January 2022

5 REFLECTIONS

The curiosity behind the present research has pushed this work development toward a concrete deepening of existing literature concepts, but, at the same time, it found obstacles in doing it. Many aspects are presented or reported from primary sources, but sometimes they cannot meet corresponding existing literature in a B2B context.

As a matter of fact, there are existing useful models in the academic press that only apply to the business-to-consumer (B2C) context. However, they would and could perfectly fit also the business-to-business (B2B) scenario: some of them, for example, are the concept of "co-design of innovation", the "born-again-global" model and the so-called "B2C lock-in effect".

The first one refers to the importance of the consumer co-design concept, due to which "companies allow consumers to actively contribute to and shape an offering during its development and design phase. Co-designing has been argued to be one of the five co-creation activities that firms could exploit to ensure market success" (Russo-Spena & Mele, 2012).

Moreover, the second refers to a "*rapid and dedicated internationalisation by 'born global' firms. Typically, these are smaller entrepreneurial firms that internationalise from inception or begin shortly thereafter. Their main source of competitive advantage is often related to a more sophisticated knowledge base that they use to exploit the dynamics of an increasingly global market environment*" (Bell et al., 2001). This time, the contrast is no more between B2C and B2B but across SMEs and MNCs.

Ultimately, the model of the B2C lock-in effect "refers to a situation in which consumers are dependent on a single manufacturer or supplier for a specific service and cannot move to another vendor without substantial costs or inconvenience" (Eurich & Burtscher, 2014)

Thereinafter, reflections on the abovementioned literature models will be presented and adapted to the present research circa the development of Hydrogen Fuel Cells between BMW and TOYOTA.

5.1 BORN-AGAIN-GLOBAL: FROM SMEs MNCs

As has been said earlier another unexplored concept is the one of innovation through internationalization: literature slightly talks about driven/pulled internationalization, but it only focuses on SMEs and their internationalization process by mentioning the "*born-again-global*" (J. Bell et al., 2001) phenomenon:

"*…their* (companies) *main source of competitive advantage is often related to a more sophisticated knowledge base that they use to exploit the dynamics of an increasingly global market environment*" (Bell et al., 2001) .

The "born-again-global", in literature, is an extension of the born-global phenomenon: firms which are not yet focused on international markets "*often possess a knowledge-based competitive advantage that enables them to offer value-added products and services*" (McKinsey & Co., 1993).

The model of born-again-global does not fit the present research because B&T are two MNCs instead of SMEs.
Collaborations and partnerships between two MNCs, characterized by two distinct corporate cultures, can be defined as global and intercultural-driven innovation: international-driven innovation puts together the two

different know-how and working cultures, driving new approaches of co-developing innovation and product development: for this reason, this aspect will be presented and integrated in the next section.

5.2 "CO-DESIGNING INNOVATION THROUGH INTERNATIONALIZATION AND MNCs"

The collaboration between B&T is the result of a collaboration between two international firms, where teams are made up by two different cultures where the term culture refers to the "*collective programming of the human mind that distinguishes the members of one human group from those of another. Culture in this sense is a system of collectively held values*" (Hofstede, 1991). More simply, it refers to a relatively stable set of values, beliefs and behaviours commonly held by a society.

Due to this, as Taras (2021) suggests, the way of approaching projects, to deal with innovation and to face challenges is something extremely linked to the company's working culture but, at the same time, diversity can address positive problem-solving outcomes (A. Reynolds et al., 2017).

The primary source's findings allowed contextualizing, with tangible examples, the relevance of a cross-cultural collaboration within an international context across two MNCs: BMW, which is based on German culture, and TOYOTA, which is a Japanese working-culture company: at the beginning of the presented collaboration, many challenges and misunderstandings were faced due to the two separate cultures.
Firstly, language barriers: Japanese hardly speak English. Furthermore, the German team cannot read Japanese letters and symbols (Hiragana and Katakana alphabet) and, due to this, there has been a constant need for an interpreter, another step or filter between the sender and receiver during communication along the used communication channel (Fig. 9).

"*Communication is the act of transmitting messages, including information about the nature of the relationship, to another person who interprets these messages and gives them meaning*" (Berlo, 1960)

Being BMW and TOYOTA's two engineering teams, engineering language is the common denominator during the development of the collaboration's products and this has been a positive aspect in understanding each other, even if the national language is totally different. This, in literature, is called *cultural field* or, more precisely, Clark & Brennan (1991) define it as *groundings.*
Germany and Japan are two big engineering cultures, and both are very technically focused.

"*The meaning of the message is grounded in the personal field of experience of the sender, which can affect how it is encoded*" (Brannen, 2004)

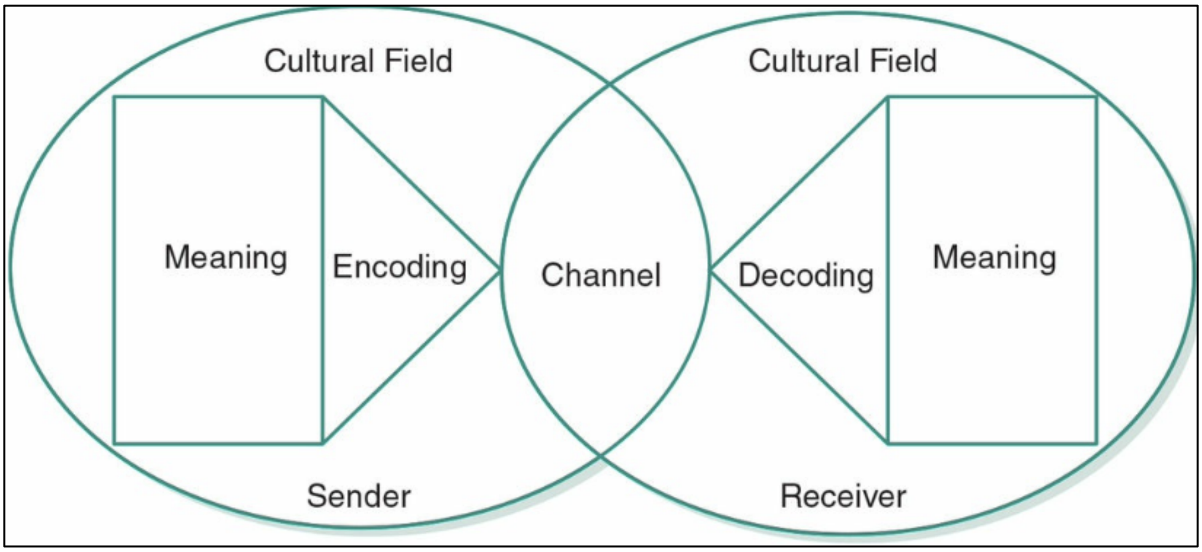


Fig. 9: Cross-Cultural communication process. Source: Adapted from Ronen (1986) and Schramm (1980).

"*For example, the Japanese work very hard on technical details; they digged out until they understand the problems. From an engineering viewpoint, we were very good together, using the same approach. In the beginning, BMW had much more computers, and TOYOTA didn't bring laptops into the meeting: they used huge sheets of paper, and this has changed over the years, now they also use the laptop during the meeting, and this is a big difference during a physical collaboration or a meeting*." (Ruecker, 2022)

5.3 "BUSINESS-TO-BUSINESS LOCK-IN EFFECT"

Once again, literature focuses on important aspects in B2C context but lacks on B2B press material. Findings shown that another crucial and negative aspect in MNCs collaboration is the one of strict dependencies on third parties: academic press already has plenty of material in the B2C context, defining it as "*Business-to-consumer lock-in effect*":

"*The lock-in effect refers to a situation in which consumers are dependent on a single manufacturer or supplier for a specific service, and cannot move to another vendor without substantial costs or inconvenience*" (Eurich & Burtscher, 2014) [34]

[34] Eurich, M., & Burtscher, M. (2014). "***The business-to-consumer lock-in effect***". Cambridge Service Alliance, 14.

As a matter of fact, the interview with Mr Ruecker has shown that this collaboration faced a significant issue on the BMW's side: it depends on TOYOTA's production of Fuel Cell, and those Fuel Cells owe also BMW's know-how.

"*TOYOTA has the main know-how on FC, we did a lot of tests together, and due to this, even our (BMW) expertise and know-how are included in the latest generation of FC. But, the physical production of FC is on TOYOTA's side, so TOYOTA is manufacturing FC in their plants, and we have to buy it from them.*
In the end, the price can be dictated by TOYOTA, so we have their new dependencies and not competition, so we have to swallow what TOYOTA says." (Ruecker, 2022)

As Gartner (2021) suggests, lock-in can result from a variety of factors including proprietary technologies, complex integrations, contractual obligations, and sunk costs associated with the deployment of existing systems.

In the business-to-consumer (B2C) context, lock-in refers to the situation in which a company is unable to switch from one service or product to another due to high costs or difficulties in migration to a new solution. At the same time, as the findings suggest, this issue can flawlessly fit a B2B scenario.

More precisely, having BMW developed fuel cells conjunctively with TOYOTA, they cannot switch to another Fuel Cell manufacturer and bargain the price simply for one reason: specialization is so high that there are no other manufacturers with this technology available, apart from other competitors (es. Nissan or Mercedes-Benz).

6. CONCLUSIONS

The present research aimed to link the paradigm of Open Innovaiton to the Automotive industry, using a case study of cross-innovation development between BMW and TOYOTA. The business case started with a common horizontal integration strategy to develop a new car model (the TOYOTA Supra model year 2019), having BMW sharing its Z4 car components and then signing a partnership to develop further and more innovative technologies: Hydrogen Fuel Cells (HFC).
Particularly, the research started from some intuition, considering the absence of mainstream news regarding the ongoing HFC collaboration (started in 2013).

In order to deliver the presented findings, two interviews took place with Mr Axel Ruecker, BMW's Program Manager at Hydrogen Fuel Cell development: those invaluable primary sources allowed the association of intuition with reality, significantly deepening the importance of OI in business growth through successful strategies seeing the collaboration of two MNCs.

The research goal has been defined through multiple research questions, together with the definition of three different hypotheses (H1, H2 and H3) and addressed through the abovementioned interviews: the use of OI is definitively positive for business growth, particularly regarding the development of innovation, cost savings and speeding up time-to-market.

Findings allowed us to highlight all the positive aspects and benefits of such a collaboration but also to provide evidence of its negative aspects, which brought this work into a reflection section: starting from cross-cultural teams working together, delivering different points of view and allowing stronger innovation (presented as co-design of innovation in an international context); toward issues regarding dependencies on third parties and allowing a reflection circa the adaptation of the B2C model of lock-in effect into a B2B one.

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8 MR AXEL RUECKER INTERVIEW

Glossary:

- **FC**: Fuel Cell
- **EVs**: Electric Vehicles
- **HFCV**: Hydrogen Fuel Cell Vehicle
- **ICE**: Internal Combustion Engine

1st interview – 23rd May 2022.

Location: Japan, Tokyo

Introduction and presentation…

L: How long the partnership about Hydrogen Fuel Cell has been going on between BMW & Toyota?

R: It started in 2013

L: the questions I'm trying to address with this research are: what are the business advantages of such a collaboration brought both to BMW and TOYOTA? Is there business growth in the two companies thanks to this collaboration?

R: the collaboration, initially, was about Fuel Cell technology and BMW wanted to catch up with Fuel Cell technology and liquid Hydrogen after we (BMW) have done a lot in combustion engine and liquid hydrogen tanks developments. Now, the next step is clean-energy projects. The idea with this collaboration was to bring in our EV know-how based on our i3 model, and TOYOTA would bring in their Fuel Cell know-how. This was the initial win-win partnership structure and strategy.

L: do you think that BMW could have been able to reach its actual innovation point without TOYOTA, regardless of the long-lasting period? Also, what could be the winning aspect from the Toyota side thanks to this collaboration?

R: the basic idea of this collaboration was to share the engineering costs, and both parties share their results and work. Of course, both BMW and TOYOTA gained benefits through sharing development costs.

L: apart from the purely technical and engineering viewpoint, Hydrogen is not something new (some projects started in BMW in the '70s); meanwhile, TOYOTA developed one of the first EVs in the '30s. Which is the political link with this mainstream energy development (EV and FCV)?

R: It's about climate change and zero-emissions driving, so we must take a net-zero direction. To address this issue, nowadays, we (BMW) have two available kinds of technologies: one is EV, and the other is Hydrogen. Both technologies will coexist, one each other because we see our customers not very happy with EV cars. They have different priorities and mobility needs: some examples are long-distance travel, businessmen driving from one customer to the next, and taxis. They drive a lot, and they don't have time to charge their vehicles. In urban areas like Tokyo, for example, it is very difficult to install all the chargers for their cars, and large residential areas and huge garages are difficult to equip with charging infrastructures for all the living people. For a massive deployment, each car should have its own charger, but this is really hard. Maybe 10-20% of our customers could be not very happy with EVs, they love their freedom, and we have to address those needs only via combustion cars and hydrogen vehicles. Even if I didn't tell you much about a close political side, this is still a political reason behind our development path.

L: this is a great explanation of the way in which BMW can follow and address its customers' needs. If I'm not wrong, at the moment, BMW is the only car manufacturer able to deliver hydrogen vehicles in the EU market. Is it correct?

R: well, yes and no. At the moment, BMW is the only one having hydrogen technologies in the passenger vehicles market, but some of our direct competitors are working on FCV Trucks and other kinds of duty vehicles. Some of the competitors that go through zero emissions with hydrogen technologies are Stellantis, Volvo, and Daimler.

L: This is strongly important for a car manufacturer like BMW to be one of the first carmakers to offer HFCV to the market.

R: it should be, but we don't know it yet. We can only see TOYOTA MIRAI and Hyundai NEXO having a market, but it's still a niche market, very small.

L: why do you think it is still a niche market? Is it for the infrastructure issue (like EV at the beginning of their path), or maybe because of a psychological customer acceptance toward this new kind of product?

R: of course, infrastructure is still an issue. Currently, in Germany, we only have around 100 fueling stations, roughly the same number in japan and only one in Italy. Of course, both cars and infrastructures have to come together; otherwise, it doesn't work.

L: What do you think could be another push for hydrogen development that may be linked to political interests?

R: There has been a huge change in the last three years, working on CO2 neutrality, and energy experts understood that we couldn't reach net-zero emissions with electricity alone. For many applications, we still need molecules and chemical elements that should be carbon neutral, and now the only thing we have is Hydrogen. There has been a huge push of the EU toward Hydrogen, with the "Repower-EU Program" about plants and places to produce clean and renewable Hydrogen. This is becoming a reality in Spain and North Africa, also to get independent from Russian Oil and Gas. Another push since Russia invaded Ukraine, in the long run, is the Hydrogen solution. After the invasion of Russia, the target of hydrogen production has been doubled for the year 2030.

L: going back to the pure collaboration between BMW and TOYOTA, being you directly involved in the team collaboration and in strict contact with your Japanese (TOYOTA) colleagues, what were your expectations by collaborating with a culturally different company and team?

R: at the beginning, of course, there were huge challenges and misunderstandings due to our separate cultures. We have language barriers (Japanese colleagues hardly speak English), we have writing barriers, we can't read the letters that the Japanese use, and we constantly need an interpreter, and we need Japanese to write in English. In the beginning, a lot of social work had to be done to build up trust and understanding. From a technical viewpoint, we don't have big differences because we (Germany) and japan are big engineering cultures, being very technically focused. For example, the Japanese work very hard on technical details; they digged-out until they understand the problems. From an engineering viewpoint, we were very good together, using the same approach. In the beginning, BMW had much more computers, and TOYOTA didn't bring laptops into the meeting: they used huge sheets of paper, and this has changed over the years, now they also use the laptop during the meeting, and this is a big difference during a physical collaboration or a meeting. We had to learn many, many things from each other. In the beginning, we had many misunderstandings and different views, but then over the years (also after building trust in relations) was very fruitful. You need a lot of time to improve your relations, draft your ideas on paper and talk to others to reach fruitful results, much more time than you would need to reach the same result only by talking to your same organization's members. That was a good experience, even after seeing where we started and where we are now.

L: is there anything you remember about something you learned from this human collaboration, and they learned something? From any viewpoint: social, engineering, managerial, technical etc.

R: one thing we learned is that Japanese work really hard to visualize the project, they take an A3 paper, and the stated information is then put into this piece of paper. It takes quite a while to align on it. In BMW, for example, we work quickly on it, and then everyone runs away., and then we have to come back working on it. In Japan, they work on it longer, but then the structure is more stable. After major decisions, their (TOYOTA) employees work straight on it. In BMW, days-weeks after major decisions are taken, we start again arguing about what has been done before. It's impressive the Japanese approach: it takes a longer time to agree, but once they agree, they start working on it following the agreed direction.

L: do you think that this kind of approach (seeing the different approach that the other party had, learning from the other) is one of the reasons for the collaboration's success?

R: for sure, this is partly a reason for the success. We both learned a lot from each other. In BMW, we learned a lot from TOYOTA Fuel Cell's know-how. We buy the Fuel Cell, and this has been a huge shortcut for BMW, allowing us to save a lot of time (about ten years) in terms of speed to reach the point where we are now. If we had developed Fuel Cell technologies by ourselves (alone), we could end the development ten years from now. With TOYOTA being where we are now, we saved about 5 to 10 years and a huge amount of money (it is hard to define the amount now). But, at the same time, we have to keep on working and buying from TOYOTA, and this is bringing issues which are dependencies.

L: what would you like to add to what we have said so far that could be useful to my research, in your opinion?

R: well, the issue of new dependencies. TOYOTA has the main know-how on FC, we did a lot of tests together, and due to this, even our (BMW) expertise and know-how are included in the latest generation of FC. But, the physical production of FC is on TOYOTA's side, so TOYOTA is manufacturing FC in their plants, and we have to buy it from them.
In the end, the price can be dictated by TOYOTA, so we have their new dependencies and not competition, so we have to swallow what TOYOTA says. If BMW develops something new, we work with a different number of suppliers, and we can negotiate the price picking the supplier with the best price/quality offer. If we start having some problems with a supplier, we can switch and replace the supplier with another. In this case, we have bargaining power with the supplier, and we can easily have substitute suppliers.

As long as companies have dependencies of both sides, being us providing other technologies to TOYOTA that they need, we can also negotiate: if you are expensive with us (with FC, for example), you will also get a high price from us. Good collaborations always have two ways of interacting. But in this era of new FC, we took the technology from TOYOTA, and we had a project (the Supra) in which we provided technology to TOYOTA to maintain bargaining power. Because they had to pay a lot for the technologies we provided for the Supra project, in the end, everything was balanced, and there was a balanced win-win. But after the Supra project stopped (and the FC project kept going on), we lost our bargaining power. For collaborations, it's always important to have a two-way collaboration where a company does not fully depend on the other.

L: thank you a lot for this plus. I only do not understand one thing. You said that in the FC manufactured by TOYOTA, there is a lot of BMW's know-how, but why has BMW not been able to learn how to develop or produce FC that is currently being developed only by TOYOTA?

R: some errors are still disclosed by TOYOTA, like production know-how being excluded from the collaboration, and this brings in new dependencies that they want us to buy their FC technologies. This a commercial agreement and a motivation from TOYOTA not to open up everything to avoid stealing know-how. Also, TOYOTA has an interest in not disclosing everything to us, and in this way, they see us both as a partner but also a customer because we are buying technology from them.

L: what do you think could be another negotiable aspect from the BMW side after the Supra project is now concluded?

R: in the beginning, it was BMW's idea to provide our Electric motors to TOYOTA as a return business (we buy FC from TOYOTA, and they buy electric motors or high-power batteries from us). But, it also came national interest into play, as you may probably know: Japan is self-depended and want to keep on being self-dependent; they do not want to depend on external companies or external countries. So Management at TOYOTA decided not to buy BMW technologies to stay independent from BMW, so they developed their own batteries and their own electric motors. So, there was no other business or project they were interested in. in terms of good collaboration, again, it should always be a two-way collaboration.

L: Yes, I realized and experienced how protectionist and conservative they are even after having studied "cross-cultural management models", like the Hofstede model.
Another question just came to my mind. Have you ever been to Japan? I've been here for a month, and along the streets, 9 cars out of 10 are Japanese. The only foreign brands you can see are BMW, Mercedes-Benz, a few Audi (European premium brands) and almost no American cars. My question is: do you think that this collaboration between BMW and TOYOTA could have been an opportunity for BMW to slightly increase its

market share here in Japan? Like a sort of TOYOTA or Japan opening doors into the Japanese market to BMW.

R: the Japanese car market is absolutely closed; it took to BMW around 20 or 3o years to get to the market share we are today, building up the business, trust, and relationship also with politicians and regulators, and yes, collaborations for sure have helped a bit this process of increasing the Japanese market share. Now, in Japan, BMW is seen as a partner of TOYOTA. You are right, Japan is very protectionist, and it also depends on how Japanese customers are willing to buy a foreign product (the Homemade bias, NDR). Unfortunately, global trade and globalism are going down at the moment, China is trying to close off a bit with Russia, and we are trying now to scale back these global independencies, and we want to bring the business back home. Unfortunately, this will make life more extensive in the end because the global work share will then be reduced, and global work share at the moment has brought a lot of wealth to all the countries and people that are somehow involved. Scaling back globalism will lead to lower income and profits in many business areas.

L: I got a lot of information from you, and at the same time, I took a lot of time with you. You gave me a lot of fundamental points for my research far beyond my initial questions. I have to thank you for the stimuli of this interview, and I will share my further findings and research development with you and with BMW, of course.

R: please, and if you have additional questions when you start developing your ideas and get deep into the research work, we can have another meeting, just don't hesitate to contact me, Luca, no problem, it is a pleasure. You can share your ideas with me, and I can help you to balance your arguments.

L: I really appreciate it, Mr Ruecker. Thank you very much again, and good luck with your projects!

R: all the best to you and your work! Bye

2nd interview: 8th August 2022
Location: Saigon, Vietnam

L: Hi Mr Rucker thank you so much for having me again with this interview, I hope you are good! Is everything fine?

R: thank you Luca for arranging this call, I've read your previous email about this call and here we are. Yes I'm fine thank, what about you? Are you still in Japan right?

L: everything is fine Mr Ruecker, a lot of things have changed and right now I'm doing this call from Saigon, Ho Chi Minh city in Vietnam! It's amazing. A lot of things have also changed about my research's topic, have you seen? Just a few weeks after we had our call in May, EU announces a stop in sales and production of ICE starting from 2035. What do you think about? And particularly, what is the sentiment inside BMW?

R: Yes definitely it has an impact, even if actually it's still an announcement. Nothing is decided yet, and processes in EU are slow (bureaucratic and political, NDR). Anyway, this is or would be only important to EU, which is only a "small" part of the world and it's not all the world. I think it will definitely have an impact on Europe and we will speed up developing or introducing zero emissions vehicles to the market, while other regions won't probably exclude the marketing of ICE cars. Many customers, as I told you last time, are not too enthusiastic about driving EVs. They love their freedom of driving anytime anywhere as long as they want. If they want to go for zero emissions, they will have to go for FC cars.
After this EU news about banning ICE cars starting from 2035, we will even more develop HFCV cars. This is our picture, and this comes alone with continuing our work with TOYOTA.

L: in our last call, you mentioned many benefits from this collaboration, but you also mentioned some limit about this partnership: BMW's dependency from TOYOTA. How is the project going, talking about this very aspect?

R: we of course continue to work together with TOYOTA, but on the other hand we also look into other opportunities with other manufacturers and suppliers and benchmark technologies to have a choice in the end. This is very important to us, even because doing so we can negotiate prices with TOYOTA if we have another option. So, you see in EU at the moment with the ongoing war in Ukraine, we still need Russian and gas, so we (the EU) have a very bad position for negotiating with Russia, because we are dependent and there are no other options available at least in the short run. Also, this is an indication that we need to be flexible and we need to "stand on more than one leg", we need to develop also an European FC industry. We (BMW) don't want to fall even deeper into other dependencies and other companies, and so to maintain flexibility and maintain our target and goal. More than one option, always.

L: exactly as you told me in our last call, power of negotiation is essential to deliver a successful collaboration without "business submission". The point of this call, to me, is to compare the information you gave me in our last call (May 2022), with the information you would give me now after EU announced ICE ban starting from 2035. How this BMW-TOYOTA collaboration – even considering it started more than 9 years ago - could play a pivotal role for BMW, being ready to this political change? Could this collaboration position BMW in a benchmark position, at least in the EU market? How would you imagine a potential present position of BMW, now, without the HFCV technologies, compared to its direct competitors?

R: uhh, very difficult question! At the moment, the advantage of this collaboration is not too big, so it should not be overestimated, because the main focus now is on EVs cars and the big competitor now is TESLA, and this competition is impacting BMW a lot, and its impacting us more than FC technologies. Actually, there's no a real HFCV market established and there is no a big competition, because the volumes are so small. There is only the TOYOTA MIRAI and Hyunday Nexo in the market, we don't see other competitors in this kind of market now. The impact of that collaboration is not decisive on BMW's future. FC technology is now taking place in trucks, and here there is a huge change in the market. We see a big change in the market that will take place in the next 5-10 years, and trucks driving will be based on HFCV. Daimler and Volkswagen, for example, are pushing a lot in trucks. Then, if a market on passenger car is developing, is easy for these companies (BMW's competitors) to downscale the FC technology they have developed for trucks into the passenger vehicles, getting quickly to the market. If this will happen , being BMW without a truck market, we could still get competitive with those companies thanks to the ongoing collaboration with TOYOTA. So, if the HFCV market takes speed, the collaboration will help a lot. But, at least in the next 3 years, it won't have a big impact to our business. My guess is at least 5-10 years.

L: My bad, I thought it was very important for a company to have such a technology ready. But now, after what you told me, I think that for a company is more important to have a big market in which to play rather than having an amazing technology without the market. Yes, now it makes more sense.

R: wait, Luca. This technology, as a product of the collaboration, is a bet on the future! This is for sure, but now it is not changing our next 5 years. There is a long-term strategy behind it. Now, this is a 9 year old collaboration, and in terms of industrial collaboration this could already be considered a very long-lasting collaboration. I have to say that this development has been slower than anyone expected at the beginning, so nobody anticipated 10 years ago that the battery technology would have had much development. So 10 years ago thought and bet on the fact that FC technology could have had a bigger impact than what it actually is. This collaboration is so long now, and we still don't have a commercial product to market. We even see at TOYOTA that they are much slower in volume than what we initially have been told. They (YOYOTA) thought that in 2020 they would have produced around 30.000 cars, but maybe they are just at 5 thousand. This is very low, and even FC roadmap of Japanese government is much slower that their initial planned.

L: Since what I see now, there is a huge distinction of HFC technologies depending on the industry they are applied to. There is car market, bus market, truck market and even aviation market.

R: yes exactly, and I will say something more to you. At the beginning of this project, Professor Mordi from Daimler told us that production number of HFCV passenger car is needed for the successful development of FC technology, and this is in terms of economies of scale withing the passenger car industry. This thinking has changed now, because the truck technology is ore needed that passenger car and the volume here doesn't matter as it does in the passenger industry. Simply because they (truck industry) have to, simply there is no options. Due to the fact that regulation has changed, and truck industry has no other alternatives, the need here of FC is more needed to go for zero emissions than passenger cars. This is what has mostly changed since I have joined the program.

L: the thesis I'm working on is between something realistic and something hypothetical talking about the investment for the future, it is even complicated to define the position of such work. This is because the technology is available, but what is missing is the market, I think.

R: yes, exactly, and infrastructure.

L: some weeks ago, a new hydrogen fuel station has been opened near Venice. This is a signal of something that is moving. Particularly now, together with the Italian PNRR and the last EU decision.

R: exactly, you have clear ideas Luca! Keep on going in this direction.

L: thank you very much Mr Rueker, these talks have been extremely important to me! Can't wait to show you my final work.

R: Good luck Luca, I hope to hear from you soon.

L: Good luck Mr Ruecker, thank you again.

• I, ……..Axel Rücker, BMW Group…… voluntarily agree to participate in this research study.
• I understand that even if I agree to participate now, I can withdraw at any time or refuse to answer any question without any consequences of any kind.
• I understand that I can withdraw permission to use data from my interview within two weeks after the interview, in which case the material will be deleted.
• I have had the purpose and nature of the study explained to me in writing and I have had the opportunity to ask questions about the study.
• I agree to my interview being audio-recorded.
• I understand that all information I provide for this study will be treated confidentially.

Signature ……………………………………

Date Munich, 23.5.2022 ……………………………

SUMMARY

Open Innovation in the Automotive Industry: How it affects MNCs' Businesses, collateral impacts and new benchmark definitions A Case Study between BMW and TOYOTA Hydrogen Fuel Cells technology development

The present work is the outcome of a personal curiosity in the automotive sector and the remarkable opportunity that I was privileged to have during my academic pursuit at LUISS University to acquaint myself with the Open Innovation paradigm. This paradigm was presented by Professor Henry Chesbrough, who is the Executive Director of the Center for Open Innovation at the Institute for Business Innovation, University of California, Berkeley. The knowledge on this paradigm was imparted to me by my LUISS University Professor, Luca Giustiniano, in his first-year Master class, "Global Design & Human Resource Management."

Since then, I have commenced an immediate and ongoing effort to contextualize the Open Innovation theory with the real-world scenario surrounding me, primarily focused on the automotive industry, which has always fascinated me.

Additionally, the present work recalls the concept of Open Innovation because of my research and analysis of BMW and TOYOTA's characteristics in various countries where I have resided in the last few months. During my stay in Japan, where I spent four months studying at Hitotsubashi University, I also worked as a research assistant at the HU Institute of Innovation and Research under Professor Ivar Padrón-Hernández.

I express my gratitude to Ken Kusunoki-sensei, who is a Professor and Faculty Member at the Hitotsubashi Business School, Yoshi Fujikawa-sensei, who is an Associate Professor and Faculty in Charge of External Affairs at Hitotsubashi Business School and visiting associate professor at the Yale School of Management, and the Director of The Institute of Innovation and Research, Yaichi Aoshima-sensei, for attempting to put me in direct contact with TOYOTA's managers and engineers.

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May 4, 2022

To Whom It May Concern:

One of my former students, Luca Bortolini, is doing his Master's thesis on the paradigm of Open Innovation in the automotive industry, particularly on the ongoing collaboration between BMW and Toyota. He is attending our Master Degree program at LUISS Guido Carli in Global Management & Politics (Rome, Italy), and is doing field work in Japan studying at Hitotsubashi University in Tokyo as an exchange student until August, 2021.

During his research visit, Luca's aim is to develop research from primary sources based upon direct interviews with high-level managers and experts. These interviews are needed because many of the details of these kinds of open innovation collaborations are not often discussed in the press. Luca also has significant curiosity and deep interest in these topics as well.

From the work he has done so far, Luca has discovered extensive collaboration between Toyota and BMW in developing finished products in internal combustion engines (ex. Toyota Supra, with BMW engines, gears and tech-instruments), and extending to new fuel sources, such as the development of Hydrogen Fuel-cell technologies within Toyota and its technology's know-how sharing with BMW.

Through the additional interviews he wishes to conduct, his aim is to get the most accurate information about this collaboration between these two major automotive manufacturers and potentially other companies as well. He is particularly interested in understanding how Open Innovation plays a pivotal role in structuring the strategies behind this collaboration, both nationally and internationally. He has already succeeded in obtaining an interview with the Chairman and CEO of BMW's Italian operations, Mr. Massimiliano Dì Silvestre.

I would personally appreciate your cooperation with him in his research. I am confident that he would be willing to share a copy of his findings from his research, in appreciation for your support.

Sincerely Yours,

Henry Chesbrough

As a scholar, the interest in this research lies in examining the Open Innovation paradigm in the automotive industry, particularly in the context of the collaboration between BMW and Toyota in developing hydrogen fuel cell technology. The research aims to demonstrate how such an industrial approach can benefit Multinational Corporations (MNCs) in their multinational business and activities, defining a new benchmark in the car industry and gaining a significant competitive advantage compared to direct competitors.

Although this research started with a very ambitious goal of creating an experimental thesis and possibly contributing to the existing literature (as it will be shown in the "reflection" section), the positive outcome of such a delicate way of collecting primary sources was only possible by interviewing a huge number of top-managers and engineers at BMW and Toyota. BMW immediately opened up to take those interviews, but Toyota never allowed a chance. Due to this, the initial ambition of doing an experimental thesis turned into a non-experimental one.

The first section of the research analyses the Toyota Supra development by applying the OI paradigm: here, Open Innovation is approached by having BMW giving its mechanical components (particularly, the BMW Z4' components) to TOYOTA, allowing it the development of the Toyota Supra (a car model), and the present research want to demonstrate the benefits of this collaboration to the B&T business in terms of sales, cost reduction, and market share increase. Eventually, the core section of the study focuses on the development of hydrogen fuel cell technology, highlighting the uniqueness of the collaboration and the potential for implementing an Open-Innovation approach in the car industry.

A necessary clarification must be made: the interest in such research started at the end of 2021. At that time, the European political environment was particularly sensitive to the so-called "green transaction", but nothing was about regulative imposition toward car manufacturers (apart from producing combustion cars above defined polluting limit). After the core hypotheses have been defined during that period (November 2021), on Jun 29 2022, the EU approved an agreement that officially stops the sale of combustion cars which will enter into force starting from Dec 31 2035. The state-of-the-art (September 2022) is represented by Germany as the pioneer European country, counting more than 97 available Hydrogen refuelling stations, having the whole of Europe counting 176.

Research questions and Hypotheses

The research in question wants to address the following research questions: *is the development of hydrogen technologies between B&T the result of an Open Innovation approach? How does Open Innovation affect strategic business and management decisions? Are there any limits or opposing sides in these strict and effective collaborations?*

In order to address those questions, as has been said, three hypotheses has been formulated:

The first hypothesis (*H1*) is that the debated collaboration between BMW and TOYOTA for the TOYOTA Supra development has been a sort of *do ut des* Open Innovation strategy to finally embrace Open Innovation in a long-lasting collaboration for the development of Hydrogen Fuel cells. Particularly, supporting the idea that BMW may have used its delivered car parts as a "bargaining chip" to gain fuel cell know-how later.

The second hypothesis (*H2*) lies in the belief that considering the harsh Japanese policies regarding foreign car brands in the Japanese market, BMW could have gained chances to increase its presence (in terms of market share) in Japan.
The third hypothesis (*H3*) is that, thanks to the Open Innovation strategic approach, BMW and TOYOTA could have defined a new benchmark in the car industry regarding the Hydrogen fuel cell technology they have been developing together. More precisely, *H3* lies in the idea that Open Innovation is definitively essential to create competitive advantage, gaining market share, and strengthen-up market presence.
Moreover, in line with the hypothesis presupposition (EU ban on ICEs starting from 2035), BMW could become a new benchmark in the European car industry in regard with its direct competitors (Audi and Mercedes-Benz), thanks to this Open Innovation approach.

Brief Introduction

Open Innovation is widely explored in the academic press regarding the automotive industry, but there is no available literature about Open Innovation in the automotive industry regarding the development of Hydrogen Fuel Cells technology.
Collaborations and partnerships are usual in a wide range of industries and often have positive impacts on the businesses involved. In the automotive industry, partnerships aim to develop car platforms, engines, and other technical components to reduce time and monetary costs, referred to as "horizontal alliances." Through an in-depth empirical analysis using primary sources, this research starts by examining the Toyota Supra and BMW Z4 collaboration as an example of a horizontal alliance in the automotive industry, aiming at exploring the development of hydrogen fuel cell technology as a significant aspect of this long-lasting collaboration: in doing this, the Open Innovation (OI) paradigm is an excellent fit for this type of conjunctive business, promoting innovation and contributing to the academic community's unexplored literature and theories.
BMW and Toyota (thereinafter B&T) are two significant players in the global car market with substantial market share, brand positioning, and innovation capabilities. They have been collaborating since 2013 to develop new car models by sharing mechanical components, improving their market presence, and working on developing hydrogen fuel cells and powertrains for 100% hydrogen-powered cars.
Hydrogen technologies (HTs) were introduced in the automotive sector between 1990 and 2006 as a solution to mitigate environmental impacts such as atmospheric emissions, fuel consumption, and noise. Despite HTs' demonstrated poor life cycle energy performance, they continue to be studied due to their potential in developing renewable energy storage, energy supply security, and decentralizing the energy system. However, there are still many unresolved concerns regarding HTs' technological life cycle, including the "chicken-egg" question of whether a lack of infrastructure hinders alternative vehicles or the other way around.

The Open Innovation paradigm, by Henry Chesbrough

The present research has its conceptual foundations in the paradigm of Open Innovation (OI), a theoretical model coined and developed by the PhD. Henry Chesbrough: this paradigm aims to create innovation thanks to the company's open boundaries instead of "closed innovation".

As Chesbrough (2003) states, Open innovation is a paradigm that encourages companies to look beyond their internal R&D efforts and actively seek external ideas, technologies, and resources to enhance their innovation performance. This concept, first introduced by Henry Chesbrough in 2003, is based on the idea that organizations can and should use external knowledge and expertise to supplement their internal capabilities to achieve better results than they could by relying solely on their internal resources.

One of the key benefits of OI is that it allows companies to tap into a wider pool of knowledge and expertise. By collaborating with external partners, such as universities, research institutions, and other companies, companies can access new ideas and technologies that they might not have been able to access otherwise. This can help companies to stay ahead of the curve in terms of innovation, and it can help them to stay competitive in a rapidly changing business environment. Another benefit of OI is that it can help companies to reduce the risks associated with R&D by collaborating with external partners, allowing companies to share all the risks associated with it while helping to mitigate the potential negative consequences of failure. OI makes companies more agile and responsive to changing market conditions. By leveraging external resources, companies can be more flexible in their R&D efforts and quickly pivot in response to changing market conditions.

The BMW Z4 and Toyota Supra Case Study

This research starts by focusing on a case of horizontal alliance between BMW and Toyota in the design and development of the Toyota Supra, a restyling of the historical Supra model launched in 1978, which was achieved with the technical components of BMW's Z4 model year 2019. This collaboration, announced in 2011, enabled the companies to share costs and risks associated with developing a new sports car platform, and to bring the new car to market more quickly. The BMW Z4 and Toyota Supra share design, performance, and technology similarities, such as a rear-wheel drive platform, a 3.0-liter turbocharged engine, advanced driver assistance systems, and similar suspension and braking systems. The cost savings achieved through the collaboration allowed BMW and Toyota to reduce their development costs by up to 20% and mitigate the potential financial losses that could have been incurred if they had developed the platform independently. The alliance between these two automakers proves to be a successful example of open innovation and horizontal collaboration in the automotive industry.

Hydrogen, Fuel Cell and how does it work

Hydrogen is an incredibly versatile energy carrier with a lot of potential in the transportation sector. Fuel cell vehicles (FCVs) powered by hydrogen have several advantages over traditional gasoline-powered vehicles. They offer higher efficiency, lower emissions, and reduced dependence on fossil fuels.

One of the main benefits of hydrogen is its efficiency. FCVs can convert a much higher percentage of the energy in hydrogen into useful work compared to internal combustion engines (ICEs), which are only about 20-25% efficient. FCVs, on the other hand, can convert up to 60% of the energy in hydrogen into useful work, meaning they can travel further on the same amount of fuel. This has the potential to reduce the overall cost of transportation and the need for refueling.

Another advantage of hydrogen is its ability to reduce emissions. FCVs produce no tailpipe emissions, as the only by-product of the fuel cell reaction is water vapor. In contrast, ICEs produce a range of pollutants, including carbon monoxide, nitrogen oxides, and particulate matter. By cutting emissions, hydrogen transportation can improve air quality and combat climate change.

Moreover, hydrogen can help reduce dependence on fossil fuels as it can be produced from different sources, including natural gas, water, and renewable energy. This means that hydrogen can be used as a transportation fuel even in places where fossil fuels are not readily available. Additionally, hydrogen can be produced using renewable energy sources such as solar, wind, and hydro power, making it a potential emissions-free fuel.

Fuel cells can convert fuel into electrical energy without needing to be recharged or run down like batteries. The most common type of fuel cell is the polymer electrolyte membrane (PEM) fuel cell, which uses hydrogen as fuel and oxygen from the air as the oxidant. PEM fuel cells consist of several layers, including an anode, a cathode, and a polymer electrolyte membrane. When hydrogen is supplied to the anode, it is split into protons and electrons, and the electrons create an electrical current. One advantage of PEM fuel cells is that they can operate at low temperatures, making them suitable for transportation and portable power applications, but they can be costly due to the platinum catalyst used in their construction.

BMW and Toyota's history with FCVs

In 1973, a big oil crisis happened. In this scenario, the world was slowly waking up from the nightmare of potential life without petroleum products and, particularly, the transportation industry. During this crisis scenario, BMW was one of the first transport-related manufacturers to get serious about replacing 'gas' – the North American petrol - with natural gas (H2). For their research and development work, the Bavarian luxury carmaker collaborated in 1979 with the German Center for Air & Space Travel (Deutsches Zentrum für Luft und Raumfahrt; DLR). For containing the super cold liquid H2, Messer Griesheim GmbH [Ltd] assisted with developing and fabricating cryogenic tanks. One of the 5-series cars was fitted with tanks for both petroleum and hydrogen fuels and was named '520H'. Immediately after the 5-series production, the 7-series powered by hydrogen was presented in New York in 2000 (called BMW 750 hL,). Currently, BMW is planning to sell its first mass-market-oriented car starting from 2023, and it will be the BMW iX5On the other hand, Toyota's FCV development started in 1992 with the first so-called Fuel Cell Hybrid Vehicle (FCHV), which was first released in 2002 (named FCHV-1) and was based on the Toyota Highlander. But, in respect of BMW, TOYOTA is still the first automaker in the world to sell an FCV in the consumer market: due to its belief in Hydrogen as a leading energy carrier, it started selling its first consumer-oriented FCV in 2014, namely the TOYOTA MIRAI, then restyled in 2022.

During its R&D decades, TOYOTA has dramatically improved Fuel Cells' technical specs and addressed three of the main issues:

- **Range**: the cruising range was increased to more than 500 km;
- **Working temperatures**: cold start was enabled from – 30°C;
- **Refuelling times**: lowered to about 3 minutes (more than ten initially)

Primary source's findings

Despite the non-availability from the TOYOTA side, primary source collection has been possible thanks to the availability of BMW: Mr Axel Ruecker, Program Manager Hydrogen Fuel Cell at BMW, immediately opened up to take the interview on the present research's topic. During his development-related role at BMW, Mr Ruecker has been directly involved in managing the cross-cultural team of BMW and TOYOTA, working together as two engineering teams.

The interviews positively addressed the research questions, not only confirming the initial hypothesis but deepening the starting points of the research itself.

Firstly, the collaboration between BMW and TOYOTA in developing Hydrogen Fuel cells definitively results from an Open Innovation managerial approach. Moreover, the interview confirmed the *do ut des* hypothesis of giving TOYOTA crucial Supra's components in exchange for gaining significant know-how and business benefits under the hydrogen viewpoint. This first hypothesis is confirmed not only by the interview itself but is supported by data presented in Tab. 1 and Graph. 1, showing respectively the car brands market-share in Japan and the foreign brands market share trend in the Japanese car market: BMW's increase in Japanese market share was possible *also* thanks to the collaboration with TOYOTA because "*now, in Japan, BMW is seen as a partner of TOYOTA*" (Ruecker, 2022).

*H1*and *H2* are confirmed.

For what concerns the hypothesis of BMW becoming a new benchmark in the EU Automotive industry compared to its direct competitors, the interview's findings partially confirm H3: in fact, Mercedes Benz is developing in-house FC technology for its trucks (BMW does not have a truck market) and its long-term strategy, when Light Vehicles (LVs) will become relevant in the market, is about scale down their technology to their car segments. H3 is considered partially confirmed because the initial hypothesis was about BMW having a unique competitive advantage: with this Open Innovation approach, delivered together with TOYOTA, BMW gained a significant competitive advantage, even if it's not 100% unique.

"*We see a big change in the market that will take place in the next 5-10 years, and truck driving will be based on HFCV. Daimler and Volkswagen, for example, are pushing a lot in trucks. Then, if a market for a passenger car is developing, it is easy for these companies (BMW's competitors) to downscale the FC technology they have developed for trucks into passenger vehicles, getting quickly to the market. If this happens, being BMW without a truck market, we could still get competitive with those companies thanks to the ongoing collaboration with TOYOTA. So, if the HFCV market takes speed, the collaboration will help a lot*". (Ruecker, 2022)

Eventually, *H3* is confirmed.

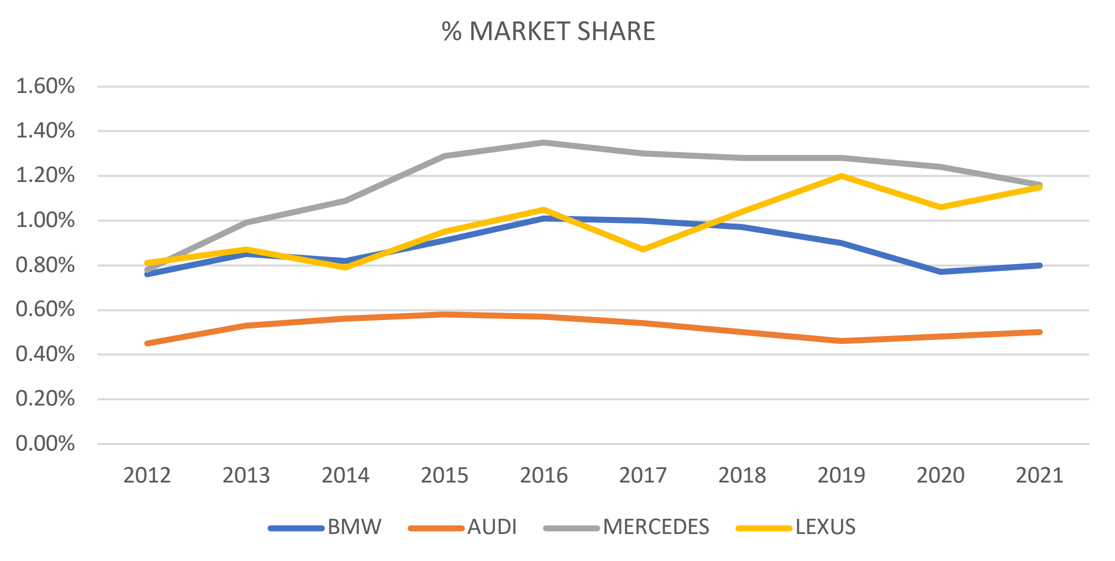
The abovementioned finding also partially answers the second research question by contextualising an Open Innovation approach and the respective companies' business benefits. At the same time, primary source findings highlighted some collateral effects of such a collaboration: this has been defined by Ruecker as an "*asymmetric collaboration*" (2022) due to the unbalanced benefits gained in terms of production expertise of the fuel cells and the consequent third-party dependencies: this very aspect is analysed in the reflections section, by considering a lack in academic literature regarding dependencies in B2B.

Eventually, the invaluable two interviews allowed a further in-depth analysis regarding the Open Innovation approach in terms of cross-cultural teamwork, considering the social and professional benefits gained along this "*Innovation through internationalisation*".

As a matter of facts, the automotive industry in Japan has a history of protectionist policies, limiting the import of foreign cars to promote domestic production. This has been achieved through various measures, including tariffs, quotas, and non-tariff barriers, making it difficult for foreign manufacturers to enter the Japanese market. As a result, domestic manufacturers such as Toyota, Honda, and Nissan have dominated the market, benefiting from the investments in research and development and a strong domestic supply chain. This has allowed Japanese car manufacturers to capture 93.16% of the total Japanese national market share, while foreign brands have struggled to gain significant market-share.

Japanese car brands performances in Japan - 2021		
BRAND	**SOLD UNITS (2021)**	**% MARKET SHARE (2021)**
TOYOTA	1.424.380	32.02%
SUZUKI	608.379	13.67%
HONDA	579.771	13.03%
DAIHATSU	572.401	12.86%
NISSAN	451.671	10.15%
MAZDA	157.311	3.53%
SUBARU	101.312	2.27%
MITSUBISHI	77.674	1.74%
ISUZU	63.061	1.41%
HINO	60.010	1.34%
LEXUS	51.118	1.14%
FOREIGN BRANDS	301.252	**6.84%**

Table 1 – Source: ***"2021 (Full Year) Japan: Best-Selling Car Brands and Market Analysis",*** Car Sales Statistics, 11th January 2022



Graphic 1: Japanese market share of Audi, BMW, Mercedes-Benz, and Lexus in 2021.
Source: ***"2021 (Full Year) Japan: Best-Selling Car Brands and Market Analysis",*** Car Sales Statistics, 11th January 2022

Reflections

This research seeks to deepen existing literature concepts on the development of hydrogen fuel cells in the business-to-business (B2B) context. However, there are existing useful models that only apply to the business-to-consumer (B2C) context but could fit the B2B scenario. These models include co-design of innovation, the born-again-global model, and the B2C lock-in effect. Co-design of innovation emphasizes the importance of consumers co-designing offerings during the development and design phase. Born-again-global firms refer to smaller entrepreneurial firms that internationalize from inception or begin shortly thereafter. Finally, the B2C lock-in effect refers to a situation where consumers are dependent on a single manufacturer or supplier for a specific service. Reflections on these models will be presented and adapted to the present research on the development of hydrogen fuel cells between BMW and TOYOTA.

Born-again-global: from SMEs to MNCs

One unexplored concept in literature is the idea of innovation through internationalization, which has only been discussed in the context of small and medium-sized enterprises (SMEs). The "born-again-global" phenomenon is an example of this, where companies leverage their sophisticated knowledge base to offer value-added products and services in global markets. However, this model is not applicable to the current research on collaborations and partnerships between two multinational corporations (MNCs) with distinct corporate cultures. This type of partnership can be defined as intercultural-driven innovation, where the two companies combine their know-how and working cultures to co-develop innovation and product development. This aspect will be discussed further in the next section.

“Co-designing” Innovation through Internationalization and MNCs

The collaboration between BMW and Toyota brought together two different working cultures, noting that term culture refers to a relatively stable set of values, beliefs and behaviours commonly held by a society. As Taras (2021) suggests, a company's working culture affects how projects are approached, innovation is dealt with, and challenges are faced. However, diversity can lead to positive problem-solving outcomes (A. Reynolds et al., 2017). The collaboration faced several challenges due to the language barrier between the two teams, with Japanese and German languages being entirely different. This led to the need for constant interpretation during communication, which could be a hindrance to communication effectiveness. However, as both teams were engineering-based, they shared a common technical language that enabled them to understand each other, even with different national languages. This is known as cultural field or groundings in literature.

Business-to-Business lock-in effect

The existing literature regarding the “lock-in effect” mainly focuses on business-to-consumer (B2C) contexts, defining it as “*a situation in which consumers are dependent on a single manufacturer or supplier for a specific service, and cannot move to another vendor without substantial costs or inconvenience”* (Eurich & Burtscher, 2014), overlooking the importance of B2B press material. The lack of attention to this area leaves out an important negative aspect of MNC collaboration, which is strict dependencies on third parties. The “lock-in effect,” defined as a situation where consumers are unable to switch to another vendor without significant costs or inconvenience, is a common problem in B2C, but this issue can also affect B2B. In an interview with Mr. Ruecker, it was revealed that BMW's collaboration with TOYOTA faced significant issues as BMW depends on TOYOTA's production of Fuel Cell, a situation that results in a lack of competition and strict dependencies. Specialization in this technology is so high that there are no other manufacturers available. As Gartner suggests, lock-in can result from various factors, including proprietary technologies, complex integrations, contractual obligations, and sunk costs associated with the deployment of existing systems.

Conclusions

The present research aimed to link the paradigm of Open Innovaiton to the Automotive industry, using a case study of cross-innovation development between BMW and TOYOTA. The business case started with a common horizontal integration strategy to develop a new car model (the TOYOTA Supra model year 2019), having BMW sharing its Z4 car components and then signing a partnership to develop further and more innovative technologies: Hydrogen Fuel Cells (HFC).

Particularly, the research started from some intuition, considering the absence of mainstream news regarding the ongoing HFC collaboration (started in 2013).

In order to deliver the presented findings, two interviews took place with Mr Axel Ruecker, BMW's Program Manager at Hydrogen Fuel Cell development: those invaluable primary sources allowed the association of intuition with reality, significantly deepening the importance of OI in business growth through successful strategies seeing the collaboration of two MNCs.

The research goal has been defined through multiple research questions, together with the definition of three different hypotheses (*H1*, *H2* and *H3*) and addressed through the abovementioned interviews: the use of OI is definitively positive for business growth, particularly regarding the development of innovation, cost savings and speeding up time-to-market.

Findings allowed us to highlight all the positive aspects and benefits of such a collaboration but also to provide evidence of its negative aspects, which brought this work into a reflection section: starting from cross-cultural teams working together, delivering different points of view and allowing stronger innovation (presented as co-design of innovation in an international context); toward issues regarding dependencies on third parties and allowing a reflection circa the adaptation of the B2C model of lock-in effect into a B2B one.