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Impact of digital transformation on the automotive industry

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ABSTRACT

Digital technologies are transforming the automotive industry and disrupting traditional business models. New business opportunities related to Industry 4.0 are emerging, so companies must adapt to the new environment.

The study presents an application of fuzzy-set qualitative comparative analysis (fsQCA) to analyze the future impact of digital transformation on business performance models and the different actors' satisfaction. A wide range of aspects and actors derived from the digital transformation process in the automotive industry are considered.

The study covers connected and autonomous driving, mobility as a service, digital information sources in car purchasing, big data, etc. The disruptive effect of the gradual introduction of electric vehicles into the market is also considered, which is boosted by environmental policies on climate change and directives for the potential use of renewable energy sources to power electric vehicles.

On the other hand, the study analyses the impacts of digital transformation on the automotive industry from the point of view of different actors, ranging from automobile manufacturers, service providers, public transportation providers, and consumers to governments.

The methodology has been successfully applied to a complex case study-based empirical analysis. It presents a novel application of fsQCA to digital transformation in the automotive industry in Spain.

The conclusions show that it is necessary to invest in adequate measures for adaptation to digital transformation, and manufacturers will end up having greater profits, productivity, and competitiveness. From the point of view of consumers, there will be access to more and better services and greater satisfaction with the required services.

1. Introduction

We are witnessing a time of continuous changes due to the irruption of digital technologies that are causing a transformation in the way the market and businesses operate in general. This generates a disruptive effect with respect to traditional procedures in terms of the way products are produced and exchanged, and also how business is carried out and benefits are obtained for producers and customers (Fichman et al., 2014).

The effects of digital transformation in the world are evident and they produce enormous benefits for entrepreneurs, consumers, and society in general, although there are environmental issues that must be addressed (Yoo et al., 2010; Piccinini et al., 2015; Paluch et al., 2019).

The disruptive effect resulting from digitalization has also reached the automotive industry and is the most important phenomenon in the industry's 140-year history. Digital transformation, globalization, and more severe competition are leading the way (Gao et al., 2016).

Digital transformation strategies are important because they reflect the omnipresence of the changes brought about by digital technologies in an organization (Chanias and Hess, 2016). Hence, organizations have to change traditional business models, which have been robust for many decades, and transform their organizations to adapt to these trends, e.g. car-sharing platforms or new telematic services (Kotarba, 2018; Riasanow et al., 2017).

The factors that affect the automotive industry, with increasing influence and complexity, are diverse (Winkelhake, 2019; Fritschy and Spinler, 2019; Wells et al., 2020; Dziallas, 2019). These factors include, in particular, globalization, which gives manufacturers the opportunity to expand into new markets, the diversification of consumers, and the accelerated modification and diversification of products. The diversification of consumers will contribute to new patterns of behavior and the need to satisfy their tastes individually, while the diversification of products will imply the reduction of the lifecycle of models to react to the fast and changing demand of consumers with innovative products (World Economic Forum, 2016). The average lifecycle of a vehicle used to be eight years, while today manufacturers have changed and

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modified their models within a space of 3 years (Jain and Garg, 2007).

Nowadays, digital technologies in vehicles represent at least 50% of the total value of a vehicle (CCOO, 2018). The integration of software and hardware has increased not only the functionality of a car but also its complexity. Key aspects have been identified that contribute to accelerating the process of digitalization of the automotive sector, such as driver connectivity, location-based services, and the type of driver based on their tastes and preferences, a feature that did not exist 20 years ago. Another key aspect is autonomous driving, where drivers will only need to press a button to go to their destination. In this regard, assisted driving and autonomous driving can be highlighted. Assisted driving covers functions for assisting the driver, which will become increasingly common until the driver becomes a passive element in the transport process, while autonomous driving entails that vehicles are capable of moving and navigating on their own in adequate traffic conditions on all types of roads (Farahani et al., 2017).

Digitization will bring significant improvements to the value chain by boosting efficiencies, reducing costs, and generating greater collaboration and innovation. It will make it possible to evolve from business-to-business approaches through their dealerships to a business-to-consumer model, with new ways of engaging with customers and partnerships with suppliers interacting through data. Increasingly connected vehicles will change business strategies from selling a product to offering value focused on customer experience (Marcus Hoffmann, 2019). According to Accenture (2017), digitization will influence the connected supply chain, which has the advantage of cost reduction and better management of the whole process from the beginning to the end. Additionally, digital manufacturing will play a major role, with new generations of robots that allow multiple assemblies, and the increasing importance of robotics, artificial intelligence, and the internet, which will be part of the new industrial revolution.

Other factors should also be considered in the digital transformation of the automotive industry. The effect on the retailer, which covers manufacturers, the sales force, and consumers, which is dynamically redefining the way they interact and communicate with each other. Moreover, clients expect a fluid interaction both physically and digitally when buying products or services. Maintenance and connected services, which will provide predictive maintenance, are sophisticated diagnostic systems. For instance, intelligent components and ubiquitous connectivity will allow certain components to send a signal when they need maintenance or replacement. Digital transformation in the aftermarket will facilitate both hardware and software updates, but manufacturers and suppliers should make their systems compatible. The car data market will also be a key factor, where the commercial promise of more precisely targeted customer offers, new business models, and increased efficiency from data and analytics will make these new businesses a veritable gold mine for automotive players. Furthermore, V2V and V2I connected infrastructures (Vehicle-to-Vehicle and Vehicle-to-Infrastructure, respectively) are key enablers of intelligent transportation, which will create an integrated communications network of continuously moving digital information to increase safety and improve traffic flow. They cover sensors, transponders, radio-frequency identification (RFID) readers in the road, traffic lights, bridges, and parking lots.

In addition, customer experience has been and will continue to be a key differentiator in the automotive market, whether during the sales process, the in-car driving experience, or in the aftersales market.

As for electric vehicles (EV), there will also be competition between manufacturers to deliver the latest EV model. An area that will attract special interest and will be a challenge is the aftermarket.

Currently, original equipment manufacturers (OEMs) are investing heavily to adapt to these trends. However, it remains unclear which technologies will prevail, leading to tensions in the automotive industry, as OEMs do not want to give up their leadership in products and technology (Simonji-Elias et al., 2014; Farahani et al., 2017).

The present paper analyses how digital transformation impacts the automotive industry in Spain from the point of view of the different actors, ranging from automobile manufacturers, service providers, public transportation providers, and consumers to governments. This includes the role of new actors that are arising due to digitalization transformation in the automotive industry, such as mobility service platforms, i.e. private or commercial car sharing, peer-to-peer (P2P) lending, or service platforms from OEMs.

The methodology applied enables us to define the trends and effects of digital transformation in the automotive industry. The purpose is to provide a set of measures to be undertaken by the automotive industry in order to remain competitive within the context of digital transformation. This is measured by the actors' satisfaction while considering a wide range of factors or conditions. Among these factors, several impacts are analyzed, such as the disruptive effect of electric vehicles, the obligation to comply with environmental regulations, and the emergence of new business and services. By knowing the actors' satisfaction regarding these aspects, the automotive industry can come up with better strategies for future adaptation to digital transformation. Eventually, it can be used as a Decision Support System (DSS) during the decision-making process for the different actors.

The results show how digital transformation will rapidly change the global landscape of the automotive industry. Consequently, the measures to be adopted to favor the digitalization process and, ultimately, the effectiveness of production, sales, and connectivity processes with the user/client will be presented.

In the discussion and conclusions section, the paper's outcomes are summarized and further research is proposed regarding digital transformation in the global automotive industry.

2. Material and methods

2.1. Theoretical framework

In recent years, fuzzy-set qualitative comparative analysis (fsQCA) has gained popularity among scientists with an interest in analyzing and comparing data that are associated with cases. Although it was primarily applied to political science and sociology, nowadays it is exhaustively applied in many areas of research (e.g. Berbegal-Mirabent and Llopis-Albert, 2015; Llopis-Albert, Merigó, Xu, & Liao, 2017; Llopis-Albert and Palacios-Marqués, 2016; Llopis-Albert et al., 2018; Llopis-Albert et al., 2019). fsQCA is an empirical method based on Boolean algebra that allows for a configurational examination of the causal relationship between a set of conditions and a related outcome (Ragin, 2008). The methodology enables a systematic cross-case comparison and leads to a case-sensitive approach. The methodology is especially suitable for cases with small data samples and favors the generalization of conclusions for larger populations. In addition, it overcomes some of the limitations of strictly qualitative or quantitative methods and allows for complex causations, counterfactual analysis, and systematic analysis of conjunctural causal patterns.

The theoretical aspects of this comparative method are explained in detail in Mendel and Korjani (2012, 2013), but the main principles are those based on conjunctural causation. This means that usually not one factor but a combination of factors will lead to the outcome, different combinations of factors may lead to the same outcome, and one condition can provide different impacts on the outcome, depending on its combination with other factors and the context (Rihoux 2007).

The term 'conjunctural' refers to the fact that it is generally a combination of factors (referred to as a configuration) rather than a single factor that leads to an outcome. Therefore, not only the presence but also the absence of a specific factor may be influential to reach the outcome and, hence, is measured. That is, QCA logic considers that different factors are complementary and often interdependent. Even if the influence of one factor is small, it might be necessary to trigger another factor, hence contributing to the overall outcome (Ragin, 2008).

As a result, the fsQCA method offers a set-theoretic approach to causality analysis due to its capability of identifying and assessing different combinations of conditions that describe certain outcomes. The method assumes complex causality and focuses on asymmetric relationships to determine which combination of factors -named as a configuration or pathway- is minimally necessary and/or sufficient to attain a certain outcome, rather than focusing on how one individual independent variable relates to the outcome. In addition, it makes it possible to identify which groups of cases share a specific combination of conditions (Meyer et al., 1993). A condition is necessary if a specific outcome cannot be achieved in the absence of this condition, while a condition is sufficient if it leads to the outcome by itself, without the presence of other conditions (Ragin, 2008). Furthermore, it allows us to deal with the concept of equifinality, which refers to the fact that multiple coexisting configurations may lead to the desired outcome.

The application of fsQCA to cross-case evidence comprises four different steps: (1) selecting cases and factors; (2) performing a calibration procedure on the available information; (3) constructing and reducing the truth table; and (4) analyzing the results.

Once the cases and factors have been selected, variables must be transformed into sets according to their degree of membership in a given condition. This is performed based on theoretical or substantial knowledge external to the empirical data, which allows meaningful groupings of cases to be categorized (Ragin, 2008). For that purpose, the limitation of dealing only with binary variables is overcome using a fuzzy-set approach, thus making it possible to incorporate non-dichotomous conditions into the analysis. Therefore, the causal conditions and the outcome are defined as fuzzy sets, in which membership functions (MFs) must be established.

The calibration procedure is performed to transform the actors' preferences with regard to factors into fuzzy variables so that they match or conform to external standards. Fuzzy sets have the advantage that they can deal with both quantitative and qualitative measurements, thus overcoming some of the limitations of both. Moreover, fuzzy sets provide a proper solution to deal with multiple data sources, as with the problem in hand. A direct calibration method is usually followed, which consists of defining three qualitative anchors representing the degrees of membership of a certain set: the threshold for full non-membership, the crossover point indicating maximum ambiguity regarding membership of the set, and the threshold for full membership. The anchors are generated using the 5th, 50th, and 95th percentiles, respectively (Ragin, 2008). These anchors do not represent probabilities but rather transformations of the quantitative scale into degrees of membership of each category.

The next step is to construct a truth table, a matrix with 2^k rows in which k is the number of causal conditions (i.e. configuration or pathway) and each column represents a condition (i.e. condition or factor). The number 2 is selected since both the causal condition and its complement are considered. The truth table represents all logically possible combinations of causal conditions and classifies the cases according to their possible combinations. Each empirical case matches a specific configuration depending on which conditions the case meets (Fiss, 2011).

Subsequently, the number of rows of the truth table is reduced using the Quine–McCluskey algorithm (Quine, 1952). The minimally sufficient configurations to produce the outcome are obtained by means of Boolean algebra. This procedure is based on several indicators, such as consistency and coverage (Ragin, 2008). Consistency illustrates the degree to which instances sharing similar conditions display the same outcome (Ragin, 2008). Hence, it measures the degree to which membership in the solution (i.e. the set of solution terms) is a subset of membership in the outcome. Coverage expresses the empirical relevance of a solution, thus measuring the proportion of memberships in the outcome explained by the complete solution. The raw coverage indicates the share of the outcome that is explained by a specific configuration (i.e. solution). The unique coverage quantifies the share of the outcome that is exclusively explained by a specific configuration.

2.2. Case study: an overview of the Spanish automotive industry

The fsQCA approach is applied to provide insight into the impact of digital transformation on the Spanish automotive industry and to assess the respective adaptation strategies. A wide range of aspects and actors derived from the digital transformation process in the automotive industry are considered.

The study covers connected and autonomous driving; mobility as a Service (MaaS) and servitization; connected supply chain and manufacturing; digital sources in the car buying and marketing processes; shared driving and vehicle ownership; big data and analytics and the cloud; and how to guarantee safety, security, and privacy. We also consider the disruptive effect of the gradual introduction of electric vehicles into the market, which is boosted by environmental policies on climate change and directives for the potential use of renewable energy sources to power electric vehicles. In this way, the automotive industry will be forced to adapt to new government regulations in relation to greenhouse gas (GHG) emissions reduction policies and energy resource efficiency and sustainability (Rubio et al., 2019).

The methodology has been successfully applied to a complex case study-based empirical analysis. A great deal of information has been collected to conduct the study. The level of participation and the degree of influence on the measures to be undertaken for digital transformation is clearly different for each type of actor, size of company, or individual consumers, the legal system in different countries, etc.

In this regard, the methodology applied has the advantage of covering all these considerations and realities.

2.2.1. Characterization of the Spanish automotive industry

In Spain, the turnover of the automotive sector (considering manufacturing companies and suppliers) exceeded EUR 100,000 million in 2018, which implies that the sector accounts for 8.6% of the Gross Domestic Product (GDP), reaching 10% if marketing, after-sales, and financial services are considered (Fig. 1). This gives an idea of the importance of the sector in Spain (Anfac, 2018; Peters et al., 2016).

The resources that the sector has in Spain must also be highlighted. There are 9 manufacturers and 17 factories, which mobilize 70,000 people. There are 2.8 million vehicles and 1.5 million registrations, involving 160,000 people in vehicle sales and maintenance; 2.3 million vehicles are exported, representing 17.9% of national exports and 13.1% of imports; there are 29 million vehicles in Spain, and 9% of the total active population works in this sector (Anfac, 2018).

Regarding investments, automotive companies in Spain have invested as much as EUR 12,000 million in the last four years, focusing on new technologies and innovation (Fig. 2). Investments for innovation are mainly devoted to areas such as safety, energy efficiency, and the environment, but also aspects related to improving the quality of industrial processes, from adapting assembly lines to the new assigned models, which have gone from 36 to 42 and, therefore, adaptation of productivity itself. For the year 2019–2020, a dozen new models were introduced, half with an alternative version (electric, hybrid, or gas) (Anfac, 2018).

Small and medium-sized enterprises (SMEs) devoted to equipment and supplies for the automotive industry are also considered. There are more than one thousand companies, which generate 4% of the Total Industrial Gross Value Added and the same percentage of investment in R&D (4.2% of their turnover), creating 225,000 direct jobs and another 100,000 indirect jobs (Anfac, 2018).

Suppliers will increase the percentage of value added to the vehicle in the near future, due to the increase in higher value electronic systems and components. In this regard, the new scenario that occurs in the presence of connected and autonomous electric vehicles is reorienting the components demanded by vehicle manufacturers, adapting promptly to this demand.

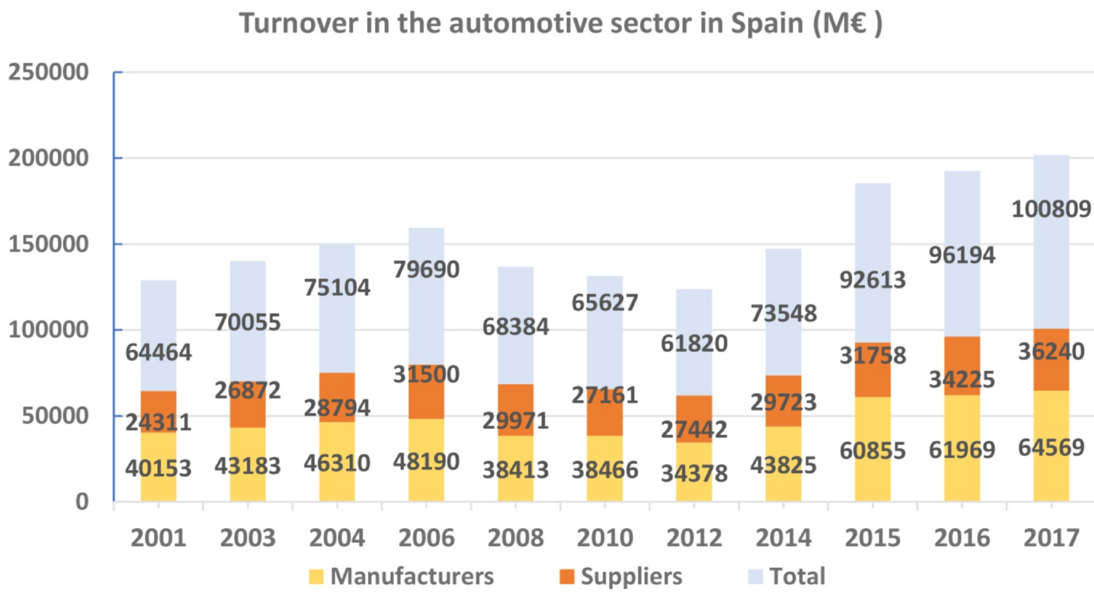

Fig. 1. Turnover in the automotive sector in Spain.

The greater complexity of these accessories (with each new car version launched on the market) results in an industry with a high presence of suppliers of first-level equipment - with a high technological level - from foreign capital, showing the weaknesses of national manufacturers due to the limited capacity for research and technological development of the majority of companies.

The internationalization of the automotive industry also plays an important role, since it makes it more difficult for Spanish industry to remain in the market for first-level equipment because the designs of the models that are assembled in Spain are decided and executed in the parent companies.

EVs only represent 0.3% of total vehicle production in Spain. Hybrid cars represent 0.1% of the total produced and natural gas vehicles 0.2%.

Financial products are playing a fundamental role in the purchase of vehicles. Funding for renting and subscription will continue to dominate, which will cover special offers such as the monthly fee with insurance, maintenance, change of tires, without an initial down payment or final fee.

Companies that supply manufacturers will be the most affected by the digitization process, as they will be forced to use new connectivity and manufacturing developments intensively, covering 3D manufacturing, computer numerical control (CNC), injection molding, reverse engineering, etc. Furthermore, commercial activity such as online sales and car-sharing will also need to be improved.

In 2017, there were 4036 dealers in Spain, covering sale and repair points, with an average annual sale of 287 cars. They are managing to maintain profitability thanks to the reduction in vehicle production costs and the increase in sales.

It is also necessary to consider policies regarding emissions and alternative vehicles in the analysis of the impact of digitalization, which has resulted in the Spanish Strategy for the Promotion of Electric Vehicles, a tool used as part of the government policy to try to reduce emissions of polluting gasses.

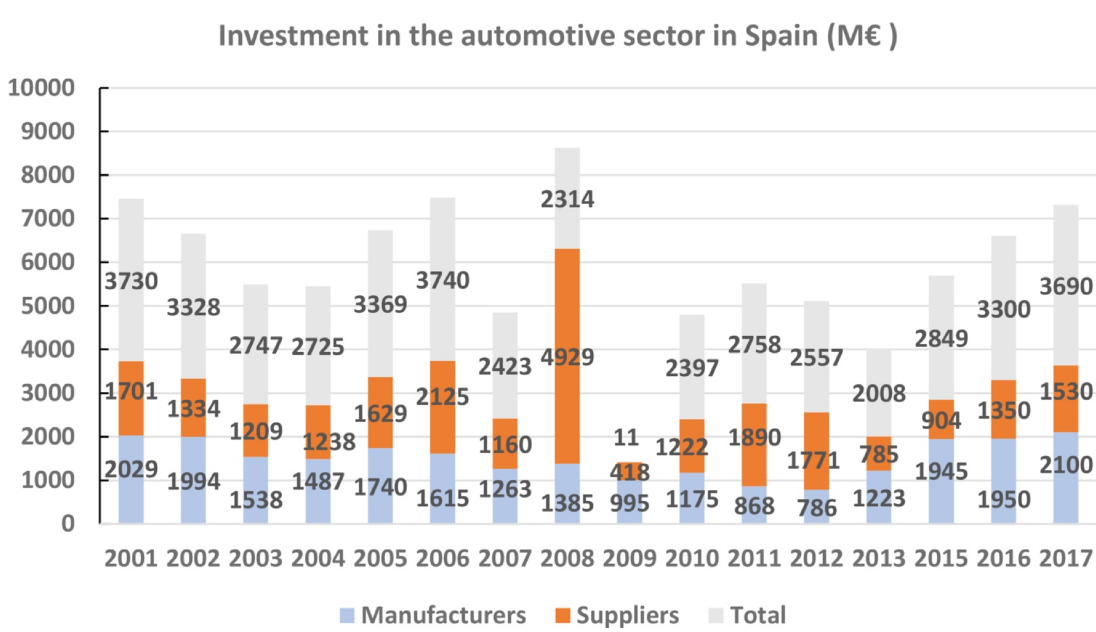

Fig. 2. Investment in the automotive sector in Spain.

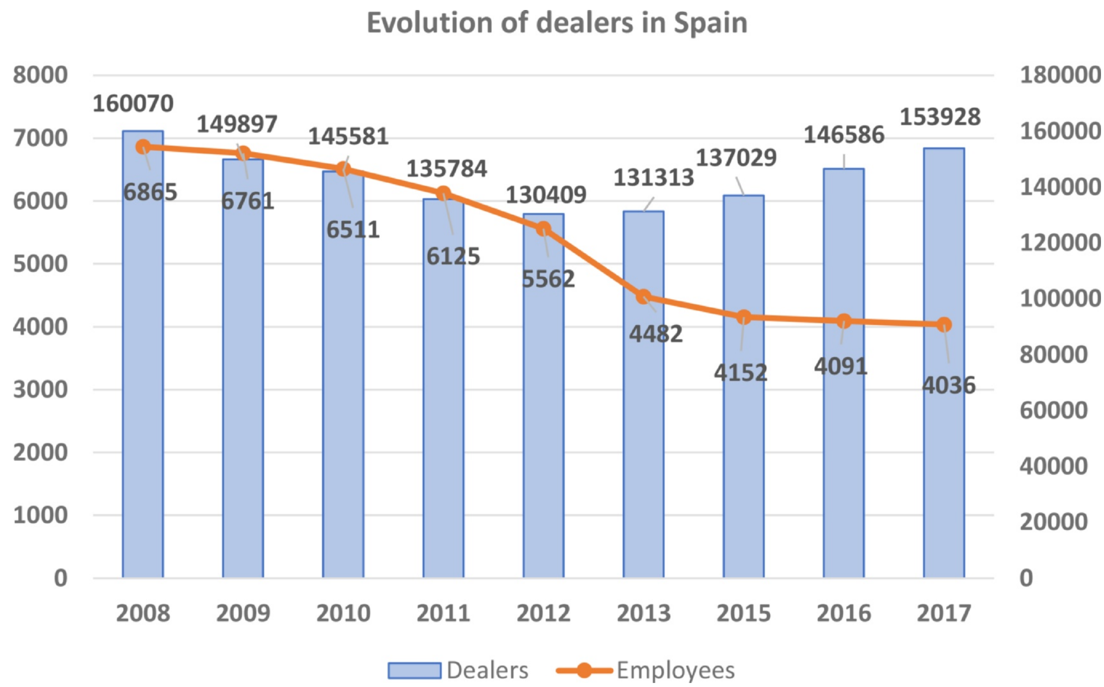

Fig. 3. Number of dealers and employees in Spain.

In Spain, diesel vehicles have a 42% share of production. The objective of an ecological transition in the automotive sector implies a comprehensive environmental approach and measures that promote the crushing of vehicles and making consistent use of the tax policy that includes registration and circulation tax.

The automotive industry faces two outstanding challenges: the integration of electric vehicles, which is changing the rules of the game in the sector, and the application of the new WLTP (World Harmonized Light-duty Vehicle Test Procedure) approval protocol, which requires significant modifications by brands in their commercial offers and ranges of vehicles, with direct consequences for Spanish factories.

3. Application of the fsQCA technique to the case study

fsQCA makes it possible to deal with uncertain environments because of the heterogeneous nature of the actors involved and the diverse factors leading to their satisfaction. Moreover, the actors' heterogeneity leads to substantially different interests with regard to how digital transformation in the automotive industry should be carried out, which complicates the problem. This technique enables the consideration of the actors' level of participation and their degree of influence when designing strategies for the implementation of digital transformation.

The outcome of the multi-criteria decision-making (MCDM) problem in hand is the actors' satisfaction. For that purpose, the point of view of different actors is considered, ranging from automobile manufacturers (including shareholders, managers, labor unions, and workers), service providers, public transportation providers, and consumers to regional and national governments. This study covers small and medium-sized enterprises (SMEs), which supply products or services to the automotive industry, and multinational companies operating in Spain.

This includes the role of new actors that are arising due to digitalization transformation in the automotive industry, such as mobility service platforms, i.e. private or commercial car sharing, peer-to-peer (P2P) lending, and service platforms from original equipment manufacturers (OEMs). A similar percentage of the different actors is used in this study to homogenize results.

The actors comprise all groups who will be somehow affected by digital transformation in the automotive industry. This covers those who have some kind of interest and those who are likely to suffer the consequences.

A great deal of information has been collected to conduct the study, including surveys, meetings, personal interviews, workshops, reports, public domain information, mass media information, and expert opinions. Furthermore, three levels of participation are considered, namely information (actors are only informed), consultation (actors express their opinions, which are considered in the decision-making process), and active involvement (actors are engaged in seeking solutions and have the power to co-decide). The level of participation and the degree of influence on the measures to be undertaken for digital transformation is clearly different for each type of actor, size of company (based on the number of employees and turnover), or individual consumers, the legal system in different regions or countries, etc. In addition, the actors' level of participation is different depending on whether it is an information procedure only (which is the case of workers and consumers of services or products, for instance, related to the acquisition of vehicles), consultation (this is the case of SMEs, which are suppliers of products or services to the automotive industry), or active involvement (which is the case of regional or national governments, multinational stakeholders, and managers). In this regard, the methodology applied has the advantage of covering all these considerations and realities properly.

Table 1 shows the conditions or factors used in fsQCA that may lead to the actors' satisfaction when designing future strategies for adaptation to digital transformation in the automotive industry. Five factors are considered, which encompass a total of forty subfactors. They cover a wide range of issues, such as management, legal, financial, and technical factors, the disruptive effect of electric vehicles, environmental regulations, and new services or business. The actors' degree of preference or acceptance regarding the factors considered is analyzed using a continuous fuzzy set.

This analysis uses fuzzy-set theory rather than simple presence/absence dichotomies or crisp sets. This is because we deal with non-dichotomous conditions (such as the actors' satisfaction), thus allowing us to address partial membership of sets.

The calibration procedure makes use of all available information and is organized using variables on interval scales or Likert scales.

Table 1
Description of the outcome and conditions considered in fsQCA, which will provide a combination of factors leading to the actors' satisfaction when tackling digital transformation in the automotive industry.

Factors or conditions (C)	Subfactors
Management, legal, & financial issues (C1)	C1.1: Feasibility of implementing digital transformation: investment costs in equipment, software, and Research, Development and Innovation departments, acquisition and installation, short implementation time of measures C1.2: Improved productivity and maximization of performance C1.3: Adaptability to changes in order to achieve flexible manufacturing systems (e.g. to address possible fluctuations in demand and failures in the production line, restriction of machines, number of workers, number of shifts, need to manufacture different products or provide services, etc. C1.4: Other costs such as payback periods, depreciation, workers' dismissals and digitalization training, social and reputational costs, maintenance C1.5: Digital sources in the car buying and marketing processes C1.6: Social equity, fairness, transparency, consensus, accessibility for all social strata C1.7: Greater profits, productivity, and competitiveness C1.8: Quality of products/services C1.9: Profit margin of products/services, annual savings C1.10: Implementation will not lead to layoffs. C1.11: Job creation C1.12: Legal framework
Technical issues (C2)	C2.1: Accessibility, connectivity, and simplicity C2.2: Autonomous driving C2.3: Connected supply chain and manufacturing C2.4: Guarantee safety, security, and privacy C2.5: User-friendliness, difficulty in handling new technologies C2.6: Capabilities and skills for implementing digital transformation
Electric vehicles (C3)	C3.1: Autonomy (driving range) C3.2: Battery recharge times C3.3: Vehicle purchase price C3.4: Number of recharge points C3.5: Repair and maintenance C3.6: Energy cost and efficiency C3.7: Tax incentives C3.8: Specific parking areas
Environmental regulations (C4)	C4.1: Greenhouse Gas (GHG) emissions targets C4.2: Use of renewable energy sources and sustainability policies C4.3: Restrictive standards defining acceptable limits for exhaust emissions of new fuel vehicles C4.4: Deadline to achieve a complete fleet of electric vehicles C4.5: Worldwide climate change agreements repercussions
New services/business (C5)	C5.1: Mobility as a Service (MaaS) and servitization C5.2: Shared driving and vehicle ownership C5.3: Big data and analytics and the cloud C5.4: Real-time services C5.5: User choice and support C5.6: Possibility of personalization C5.7: Prompt availability 24/7, deliverability C5.8: Digitalization of public transportation services C5.9: Peer-to-peer (P2P) lending or service platforms
Output	Actors' satisfaction

These psychometric scales are exhaustively employed for scaling information, which can be structured using linguistic labels. For instance, "degree of membership of the set of willingness to invest more than a certain percentage of the company's turnover for adaptation to digital transformation". Consequently, the actor's degree of agreement with regard to a certain statement can be categorized using a five-level Likert scale, for example: "strongly disagree", "disagree", "neither agree nor disagree", "agree", and "strongly agree". The conversion between these verbal labels and the fuzzy scores is performed using different qualitative anchors that structure fuzzy sets. The fuzzy scores are associated with degree of membership and range from 0 (which represents a low degree of acceptance or agreement) to 1 (which displays a high degree of acceptance or agreement). The threshold used for the different factors to represent the degrees of membership are the 5th (full non-membership), 50th (crossover point dividing "more in" from "more out" with regard to a specific statement), and 95th percentiles (full membership). The transformation into fuzzy scores must also consider the type of actor, the actors' level of participation, and their degree of influence on the automotive industry. We use the size, number of employees, and turnover of the company to homogenize results. In this way, the values obtained are more comparable across different companies and realities. For instance, shareholders, the boards of directors of multinational automotive corporations, and governments have more influence on digital transformation than small and medium-sized enterprises (SMEs), consumers, workers, and labor unions. A clear example of the different level of influence is the disruptive effect of the gradual introduction of electric vehicles (EVs) into the market and its subsequent reduction in greenhouse gas emissions, where governments and the powerful automotive industry lobbies exhibit higher influence or pressure than the other actors. This process is boosted by environmental policies on climate change and directives for the potential use of renewable energy sources to power electric vehicles. In this way, the automotive industry will be forced to adapt to new government regulations in relation to greenhouse gas (GHG) emissions reduction policies and energy resource efficiency and sustainability (Rubio et al., 2019; Rubio and Llopis-Albert, 2019). These implications have been taken into account when assigning the fuzzy scores, with the aim of weighting and homogenizing the results.

Hence, fuzzy-set membership scores are appropriately assigned to actors with higher influence and a greater level of participation. They are considered in this study to be more difficult to satisfy.

Additionally, the aggregated final score for each factor is calculated through the arithmetic average of the fuzzy scores of each subfactor. The results strongly depend on the calibration process, so that it is of

Table 2
Analysis of necessary conditions. The symbol (~) indicates the absence of the outcome/condition.

Conditions (C) tested	Consistency	Coverage
C1	0.5351	0.8396
C2	0.7405	0.7313
C3	0.8477	0.5765
C4	0.4605	0.3958
C5	0.8650	0.7104
~C1	0.6999	0.6037
~C2	0.6468	0.6350
~C3	0.6385	0.5828
~C4	0.5025	0.8715
~C5	0.5320	0.5409

the utmost importance to convert the verbal labels of the scales into metrics without any loss of information. An adequate calibration should allow us to scale the degree of membership while considering qualitative differences between actors and factors.

After the calibration procedure, a truth table is constructed and analyzed via the fsQCA 3.0 software (Ragin and Davey, 2017) and the R package (Medzihorsky et al., 2018).

Since there are five factors, the matrix dimensions are (25) rows (i.e. 32 possible configurations) and 5 columns. First, the matrix is tested for factors that are necessary for the outcome and also for the negation of those factors, expressed by the tilde (~) sign in Table 2.

A condition is considered necessary if the consistency is higher than the threshold value of 0.9 (Schneider and Wagemann, 2012). Table 2 illustrates the consistency and coverage values for all conditions. As the highest consistency value among all conditions is 0.8650, none of the variables is a necessary condition to produce the outcome. Consequently, there are not any conditions that need to be present to achieve the actors' satisfaction. This demonstrates that the actors' satisfaction depends on a wide variety of conditions due to the actors' high heterogeneity with conflicting interests.

The truth table is minimized by means of Boolean algebra using the coverage and consistency values. It leads to a set of combinations of causal conditions in which each configuration is minimally sufficient to reach the outcome.

Table 3 depicts the nine configurations that are returned by the algorithm. Following Ragin's (2008) recommendation, the intermediate solution is presented. In accordance with the notation introduced by Ragin and Fiss (2008), black circles (●) mean the presence of a factor, white circles (○) indicate its absence, and blank cells represent ambiguous factors. All configurations display acceptable consistency values (<0.80), while the raw coverage values range from 0.0507 to 0.3423. The results show a great diversity of configurations so that no unifying path explains the outcome, which implies that they are sufficient but not necessary.

The results may be distorted somehow because of the lack of adequate knowledge regarding the complex digital transformation implications of some actors (such as the consumers). As further research, it would be advisable to carry out different rounds during the implementation of fsQCA to better explain to all actors such implications and allow them to share their conflicting point of views. This would lead to more consensus about future strategies for adaptation to digital transformation.

The uncertainty in the results can be assessed by means of robust tests, which are based on several adjustment parameters such as the unique coverage, raw coverage, and consistency. Tables 2 and 3 present the validity and reliability of the results, in which those parameters show satisfactory levels of confidence in the diverse solution terms as defined by Ragin (2008).

Concerning the non-necessary conditions, the results are imprecise. Although these conditions are presented in several configurations, their absence is significant in other pathways. The absence or presence of such conditions in a specific configuration can be explained by the actors' heterogeneity.

It is worth mentioning that in order to obtain satisfactory outcomes actors should be engaged at early stages of the decision-making process and be provided with clear targets, information, and organization (e.g. suitable mechanisms to capture them and a reasonable agenda). In this way, there will be more probability that actors support decisions and are less likely to hamper them. Moreover, satisfied actors are less prone to delay the decision-making process by means of their opposition, for example, by litigation regarding the deadline to achieve a complete fleet of electric vehicles (EVs) or the imposition by the government of more restrictive standards defining acceptable limits for exhaust emissions of new fuel vehicles sold (Berry et al., 1993).

Discussion and conclusions

Digital transformation is gaining momentum in the automotive industry and will rapidly change the global landscape of the sector. Moreover, it is causing a significant shift in the way car manufacturers and service providers are delivering goods and services to the market, which is boosted by government legislation on environmental issues and high consumer demand.

The results shed light on the impact and adaptation strategies for digital transformation in the automotive industry, which is analyzed from the point of view of a wide range of actors. In this regard, this work presents the factors and measures to be adopted that the actors consider appropriate to favor the digitalization process, and ultimately its effectiveness in the production, sales, and connectivity processes with the user/client are posed.

The results show that all configurations leading to the outcome (i.e. actors' satisfaction) for all actors entail a combination of factors with high demands for improved or new digital services, increasingly competitive, economical, and autonomous electric cars, and the use of efficient renewable energy resources. The results also exhibit that there

Table 3
Analysis of sufficient conditions for actors' satisfaction.

	Configuration number								
Conditions (C)	1	2	3	4	5	6	7	8	9
C1	●	●	○	●	○		●	●	○
C2	●	●	●	○	●	○		○	●
C3	○	●	●		○	●	●	○	●
C4		●		●	●	●	○	●	●
C5	●	○	●	●	●	○	●	●	●
Raw coverage	0.1002	0.3423	0.211	0.0709	0.0507	0.2167	0.1466	0.2363	0.1227
Unique coverage	0.0855	0.0156	0.0038	0.058	0.0666	0.0738	0.0254	0.0399	0.0244
Consistency	0.8543	1.0000	0.8731	0.9172	0.8087	0.8957	0.9506	0.8871	0.8851
Solution coverage	0.6587								
Solution consistency	0.8654								

Note: 1. Black circles (●) indicate the presence of a condition, white circles (○) denote its absence, and blank cells represent ambiguous conditions.

are conditions that appear in most of the configurations leading to the outcome, for example, the implementation of new services and business (C5). Consequently, the companies that take the lead in developing new services and products related to the digitalization process will have a significant advantage to compete in the automotive industry. Therefore, the results suggest that it is necessary to invest in adequate measures for adaptation to digital transformation, and manufacturers will end up having greater profits, productivity, and competitiveness. For better adaptation to such impacts, the results lead to the conclusion that car manufacturers should carry out a major investment in digital transformation to gain a competitive advantage in the global market representing the automotive industry. This investment should encompass capital for both infrastructure projects and Research, Development, and Innovation (RDI) activities.

However, we have detected that companies are somehow reluctant to devote substantial capital to such efforts. This is because there is no immediate payoff, which entails capital risk, and the return on investment is uncertain. Note that some impacts, such as the gradual introduction of electric vehicles, have a far-reaching effect on business profits. Therefore, there is a delay between the current investment in the required technologies and the future expected benefits. As a result, a small number of organizations have completed their roll-out, while the majority are still defining their implementation procedures or performing mid-term test projects to ensure that their approach is appropriate.

Moreover, some small and medium-sized enterprises (SMEs) lack digital transformation strategies, which may cause a dramatic effect in the automotive sector in Spain in the medium and long term. This is because the high demands in terms of capital and human resources pose a significant barrier to those companies attaining digital transformation.

The actors' satisfaction strongly depends on their role in the automotive industry, which has led to a broad variety of factors being considered. For instance, the results show that manufacturers or supply chain and logistics companies pay more attention to profit and productivity, while consumers' satisfaction with regard to a product or service purchased is analyzed in terms of accessibility, connectivity, and simplicity, cost, and quality, real-time services, user choice and support, the possibility of personalization, deliverability, etc. Workers and labor unions are more interested in preserving the existing jobs, the difficulty of handling new technologies, and safety considerations.

From the point of view of consumers, the results suggest that there will be access to more and better services and greater satisfaction with the required services since they are highly demanded by them. In this regard, consumers will play a major role due to the strength to choose vehicles and services. However, they are still reluctant to buy electric or hybrid vehicles in the short run, since consumers pay more attention to the high purchase price of the vehicles, long battery recharge times, low autonomy (driving range), and scarce recharging points. Nevertheless, if any improvement is made in this regard, their lower energy cost and emissions, higher energy efficiency, lower car repair and maintenance, designation of specific parking areas, and provision of tax incentives could tip the balance in favor of electric cars. The results suggest that car manufacturers prefer gradual implantation of EVs due to the high investment required for the transition from fuel vehicles, and they oppose highly restrictive environmental regulations. Consumers, on the other hand, show the greatest awareness about environmental problems. Again, the results exemplify the conflicting and competing interests of the different actors.

In addition, consumers' opinions allow the other actors to better identify the threats and opportunities (e.g. tackling new emerging markets and services) that digital transformation poses for the automotive industry.

Finally, the methodology seeks to provide a Decision Support System (DSS) in order to address the trends and challenges of digital transformation in the automotive industry that can be used during the decision-making process for the different actors.

As further research, since the automotive sector exists worldwide, other countries should be analyzed to contrast the conclusions obtained in this case study. That is, regional and cross-country comparisons should be carried out. It would also be advisable to evaluate whether the causal configurations remain unchanged over time, consider other core factors (such as confidence in the management team), and the reliability and validity of the results when applied to other industrial sectors.

Also, digital transformation should be considered as a faster way of overcoming the severe economic slowdown due to the COVID-19 health crisis. This should be empirically corroborated in future studies about this topic.

Author statement

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Supplementary materials

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