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The Different Legislation of Automotive Recall and their Implications for Society

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Abstract

The automotive industry, like so many others, is naturally competitive. Minor errors and differences result not only in monetary losses or gains, but also in impacts that are difficult to measure, such as customer confidence in products of a certain brand, or even its reputation. Among the small differences directly at work after sales is the "invisible" action of legislation of a particular place regarding consumer rights. In order to analyze different legislation guidelines in the event of failures, this work will present the correlation between automotive recalls, call of vehicles carried out in an organized manner after the presentation of abnormal behavior due to the probable error occurred in the assembly or manufacture of the automobile, and the different laws of three regions of interest: Brazil, United States of America and the European Union. The work, after a detailed explanation of the different laws of the three regions, shows concrete relationships between the disclosures affected by the regulations of a given region and the impacts that they have on the relationship between consumer and seller, that is, on society.

Keywords: recalls, automotive industry, legislation, safety, society implications.

Introduction

Currently, the recall of vehicles in the post-manufacture period, for repairs and modifications, prevents a known defect from causing a possible accident. For Hora, Bapuji and Roth [1], Mackelprang, Habermann and Swink [2], Baraldi and Kaminski [3] and Eilert et al. [4], recalls can be divided into two main causes: defects arising from failures in product development and/or the manufacturing process.

After the definitive perception of the failure, the information must be announced to the consuming public in an ostensible and wide-ranging manner in order to reach the largest possible number of buyers of the product [5]. However, the way in which such dissemination is carried out varies between the regions studied.

In Brazil, the dissemination of a recall is regulated by the Consumer Protection Code and released by Senacon [6]. In the USA, the ads are released by the National Highway Traffic Safety Administration [7] in a monthly report [5]. In the European Union, the disclosure is made through the Rapid Alert System for Dangerous Non-food Products [8], with other products not belonging to the automotive industry.

The different laws, in the three regions, create variables that directly impact society and the recall of the product, which, therefore, for Kaminski [9], incisively influence the safety and efficiency of the product, generating risks to society in the environmental, personal and economic spheres.

From the aforementioned differentiations, it can be said that the initial reactions caused by the economic risk of the call for the automotive recall will also be divergent between the studied locations. For Schiffman and Kanuk [10], the choice or purchase decision is the initial stage of the consumption process, which includes the establishment of a set and style of the same. The experience of using products and services, such as the sense of pleasure derived from the possession, collection or acquisition of things and experiences, contributes to consumer satisfaction and to their quality of life. Thus, with different lifestyles (experiences, satisfactions and cultures) between countries, the charge derived from an imperfect purchase process (seen in the form of a recall) also varies depending on these factors.

Therefore, this study seeks to analyze the relationships between the different existing regulations, in the three regions studied, with the economic impact on the respective regions.

In order to do so, first a discussion about the recall is proposed, as well as a presentation of certain dilemmas and technical exposures. Then, a differentiation of the legislation is presented alongside a detailing of the problematic of these three regions, evaluated from their regularization mechanisms. Right after, ideas about the correlation of the disclosure of these recalls are discussed and introduced, with the use of statistical methods, respecting legislative differences, and their impact on society. Finally, analyzes are carried out and conclusions are drawn about the relationship between local legislation and other variables of impact.

The Recall

An automotive development process is characterized by a design, build and test cycle, that makes intensive use of existing knowledge in the company and from its suppliers Tier 1. This process requires high financial investments, technological resources, specialized personal and extreme care, following procedures for this development, with intensive use of the existing knowledge in the company, with a part being stored in documents generated during the process, the explicit knowledge [11]. However, even with precautions being taken, errors and failures in manufacturing, as well as in the project itself, due to accelerated deadlines or skipped steps,

can occur with the car being produced, ultimately leading to risks for the consumer and for the entire civil society.

The problem becomes emphatic if the defect or failure in a mechanism is noticed only when the product is already in circulation and being used by its consumers. If a safety-related defect occurs or even if the manufacturer suspects that this is happening, a recall must be initiated, in order to protect and preserve the life, health, integrity and safety of the user, or even, to avoid and minimize physical and moral damage.

Recalls are essentially a consumer right, since those own the right to information and security [12] and it cannot cost to the consumer, being the producer's responsibilities to warn the owner of a defective product and to make the necessary repairs to the vehicle, so that the user's safety is maintained.

In general, for any region of occurrence, automotive recalls are studied in five main steps (Figure 01): suspicion of a failure, checking for a possible defect, veracity of the failure and public disclosure, effective accomplishment (consumer presence) and, for last, termination.

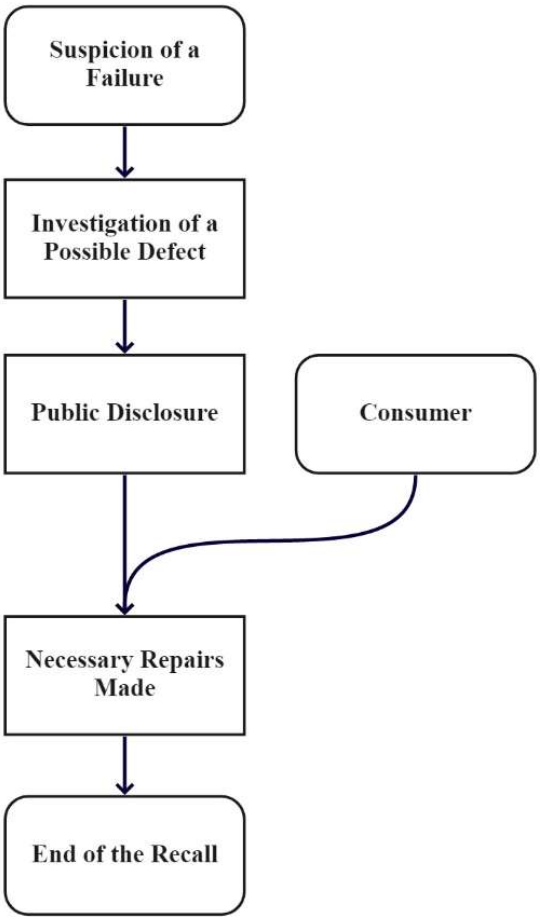

Figure 01 – General Flowchart of a Recall's Process

The first step, responsible for initiating and reasoning the automotive recall, is the reporting of a failure that may be occurring with the product. This suspicion may come from the car dealers themselves, be raised from customer complaints or, even due to possible accidents of doubtful frequency and reason that occurred with the product (Figure 02).

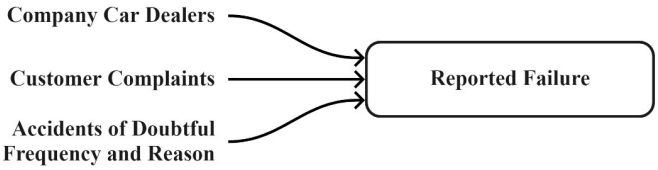

Figure 02 – Possible Three Suspicions Providers

Once automotive recalls can be categorized into two main causes: defects arising from product development and/or from the manufacturing process, consisting the possible failures to be found in the investigation, that is, in the second stage, it is necessary to go deeper into the causes and possible effects that can be found in this step. In order to do so, these causes, for Baraldi and Kaminski [3], can still be divided into more subdivisions: failures in product development into errors in development, product specifications, validations and tests and, finally, failures in the manufacturing process into errors in formulation of minor manufacturing processes, in planning control processes, in defects in manufacturing means, in incorrect storage, in damage to the product during its distribution and in use of deficient raw materials. If no defects are identified, the possibility of demanding errors of a recall is ruled out and the same does not occur. However, once an error is identified, the next step is continued.

During the third stage, the widespread disclosure of the existence of the defect, trying to reach as many consumers as possible [5], and the opening of the company to receiving products belonging to consumers occur. It is the stage where the legislation is most active, as the method of disclosure must respect the laws and regulations of each region, even if the recall is international, that is, there is the presence of defective products in more than one distinct country. In addition, it is the stage of the recall itself, since the "call" is made to the public.

The fourth stage, unlike all others, is the only one with a primary external stakeholder, the consumer. Not only needs the company to be prepared for the exchange/alteration of vehicle parts, but it must also wait for the arrival of consumers with defective products, mostly scheduled to facilitate the logistics of labor and to control the parts coming from the assembler. Due to this need, the importance of a good and complete disclosure, carried out during stage three, becomes relevant, so that, finally, it is possible to reach the largest number of customers with dangerous products operating in the community.

Once the repairs have been made to the largest possible number of vehicles and the suggested exchange period has passed, the call ends and the recall, in practice, is considered done, even though it is not, in theory, concluded, this being the fifth, and last, stage of the automotive recall process. It is worth noting that the use of the word "finalize" is the most correct in this case, along with "end", as there was no complete "conclusion", since it is not possible, in practice, to reach all defective cars and some of these are still in circulation, bringing danger to other actors in society.

These five stages, in addition to an economic impact that could reach hundreds of millions of dollars on the company, involving costs of logistics, repairs, readjustment in the assembly process and

communication [13], raise a new monetary variable that is distinct between regions, the impact of the call on the public, that is, how the target audience and the niche of buyers will respond to the process that has just ended.

Legislation

Once the stages of the studied process have been established and in order to deepen the differences between the three focus regions (Brazil, United States of America and the European Union) it is necessary, at first, to draw parallels about the different historical panoramas between them, emphasizing the legislative aspects.

The presence of government recall regulations in the three regions influences how the third stage will be conducted, which, because it is the disclosure stage, materializes in the first contact of the company with the consumer of the product at risk. Therefore, once the historical panoramas and the different regulations are understood, identities will finally be obtained between the influence of legislative norms and the impact that the occurrences of recalls in these locations generate on the consumer and, finally, the correlation between these two variables.

The Brazilian panorama, first presented, is, in addition, the most recent to be stabilized among the three analyzed regions. With a brief start, after some failed attempts in the 1970's, in 1985, with the creation of the National Consumer Protection Council (Decree nº 91.469), the obligation was only definitively realized in 1990 with the law 8078 / 1990, better known as the Consumer Protection Code (Table 01). After Brazilian mandatory requirements were established, other measures related to the application of these standards were established in the following years. However, the code and regularization basis remain the same until the current year, 2020 [14].

The second scenario to be assessed is the one of the United States of America (Table 02). There, the mandatory recall started in 1966, with the National Traffic and Motor Vehicle Safety Act, which delegated to NHTSA the authority to issue / create vehicle safety standards and require automakers to take responsibility for vehicles with defects related to safety, or that do not correspond to the Federal Safety Standard [7]. In addition, there is the US Code Title 49 - Transportation, which was promulgated in 1978. The text is one of the titles published by the Office of the Law Revision Counsel, which aims to codify and categorize the constitution's definitions by subject and thus discuss on the permanent laws of the USA, functioning as a Joint Ordinance, if it were possible to compare, in a didactic way, to the Brazilian legislative case [15].

In contrast to the information from USA, it is possible to proceed to the third and last panorama to be analyzed, the European case and, thus, to gather and organize historical information, of the same category and character as that obtained for the other regions, in Table 03.

Since it was founded and organized only in 1993, the European Union does not have an extensive history of its laws, since countries already had their own regulations even before joining the bloc. Therefore, it is not within the scope of our study to discuss the individual history of each country and the focus will be redirected to the laws registered in the post-foundation period of the bloc.

The regulation of recalls, including the case of automotive recalls, in European Union, is formalized by the GPR Regulations (or Directive or General Product Safety Regulations), formally called Directive 2001/95/EC, established by the European Parliament and the Council of European Union in December 2001, and becoming effective only in January 2002 [8]. One of the objectives of Directive 2001/95/EC is to ensure that products placed on the European Union market are safe, defining the obligations and powers of member states, through the identification of "competent authorities", from each member country, which will monitor and verify the safety of products, as well as complaints and, in addition, collaborate with producers and distributors through notifications, withdrawals/sanctions and recalls; and the obligations and powers of producers/sellers, defining that only safe products can be offered for sale and that any risk associated with the product must be informed to buyers, in addition to having the obligation to ensure that any product placed on the market can be traced and thus removed to avoid risks to the consumer [8].

Under the Directive, a product is considered safe if it meets all conditions of the European statute and the national law of the country in which it is located. If there are no European Union regulations or standards, product compliance is determined according to other document references, such as national standards, recommendations to the Commission and codes of practice [8].

The GPS Regulations are valid until today (2020) and can be read, in full, in the first language of all the countries in the block and in English.

Finally, there is the gathering of information necessary to make an analysis about the relation between these events of emergence of regulations and the impact of disclosure of a certain recall to the customer, after the passage of the third stage of the process, and how this will affect future, considering and exposing the differences between the three regions studied.

Table 01 - Historical Summary of Legislation regarding Automotive Recalls in Brazil

Year	Event	Description
1971*	**Bill 70/1971** ***(Projeto de Lei 70/1971)***	Project intended to create the Consumer Protection Council
1977*	**Parliamentary Committee of Inquiry** ***(Comissão Parlamentar de Inquérito)***	Designed to ascertain non-compliance with technical requirements with respect to quantity, quality and durability and safety of goods delivered for consumption and the methods adopted for their dissemination
1985	**Protection Council – Decree No 91469** ***(Conselho Nacional de Defesa do Consumidor – Decreto No 91469)***	Disciplines the public civil action for liability for damages caused to the environment, to the consumer, to goods and rights of artistic, aesthetic, historical, touristic and landscape value and takes other measures
1990	**Consumer Protection Code – Law 8078/1990** ***(Código de Defesa do Consumidor – Lei 8078/1990)***	Provides for consumer protection and other measures, including mandatory recall and its rules
1993	**Law 8656/1993** ***(Lei 8656/1993)***	Changes the provision of fines and penalties, in case of violation, of Law 8078/1990
1997	**National Consumer Protection System – Law 2181/1997** ***(Sistema Nacional de Defesa do Consumidor - Lei 2181/1997)***	Provides for the organization of the National Consumer Protection System - SNDC and establishes the general rules for the application of administrative sanctions provided for in Law No. 8078
2019	**Joint Ordinance No 3 - 2019** ***(Portaria Conjunta No 3 – 2019)***	Disciplines the procedure of calling consumers - recall, for replacement or repair of vehicles that are considered harmful or dangerous after their introduction into the consumer market.
2019	**Joint Ordinance No 618 - 2019** ***(Portaria Conjunta No 618 – 2019)***	Disciplines the communication procedure of the harmfulness or dangerousness of products and services after being placed on the consumer market

Label: (*) – No Longer Valid in 2020

Table 02 - Historical Summary of Legislation regarding Automotive Recalls in USA

Year	Event	Description
1966	**National Traffic and Motor Vehicle Safety Act**	Gives NHTSA the automotive vehicle safety authority, including recalls disclosure and their mandatory in case of health risks
1978	**U.S. Code: Title 49 -Transportation**	Dissertation on permanent US laws related to transportation, including recall procedures

Table 03 - Historical Summary of Legislation regarding Automotive Recalls in EU

Year	Event	Description
2001	**Directive 2001/95/EC (General Product Safety Regulations or GPS Regulations)**	Establishes safety rules and standards for non-food products in the European Union, including mandatory recalls

Impact Correlation

Once the historical processes of the three regions of interest have been studied and presented, we can proceed to the next step necessary for the formulation of conclusions and analyzes, the impact that the recall has on consumers' opinions about the sector, in short, to infer grounded information.

Methodology

To obtain numerical data about the impact measurement, we will consider the use of Pearson Correlation Coefficient on two data vectors. Such coefficient is given by:

$$p = \frac{cov(X,Y)}{\sqrt{Var(X).Var(Y)}} \quad (1)$$

where X and Y are two variables, which can be interpreted as two vectors or as two sets of data, *cov* is the covariance between these two sets and *Var* is the variance calculated for a group of data.

Pearson coefficient, also called Pearson's product-moment, represents both the magnitude of the relationship force between the two vectors and the direction, which can be negative or positive. In addition, it is a dimensionless element that can have values between -1 and +1, where -1 represents a perfect negative linear correlation and +1 represents a perfect positive linear correlation. The closer the coefficient gets to the extremes (-1 or +1), the stronger the relationship between the data sets. Finally, a Pearson coefficient of 0 indicates that there is no association between the measured variables [16].

For the specific case of recalls analysis, this coefficient will be applied for certain data conditions. First, we will apply the Pearson coefficient calculation between the vector number of recalls in a given country over the years (be it vector X) and the vector that represents the rate of new registered vehicles, considering the consecutive year (so that it is possible to evaluate the impact after the occurrence of the recalls), in the same country during the same period of years (let this be the vector Y). Thus, in this first application, we will be able to understand the correlation that the number of recalls has with the purchase, indirectly, of cars by consumers in the three regions studied.

After this first analysis, the same method will be applied to two more vectors of interest, the first will be the number of cars affected by calls over the years in a given location, this being the vector Z, while the second will be the same set of data Y used previously, that is, the rate of new registered vehicles in the same location over the same period of years. It will be possible, with this second application, to understand how the consumer of a given region reacts to the number of cars impacted by recalls, and not to the number of events per se.

Finally, once with the two previous applications made, a third calculation will be carried out, this time of less complexity: a ratio between the indices previously found, in the exposed order, for a later verification if the consumer reacts more, in the exposed location, to the number of calls or to the number of cars affected and, thus, allowing a comparison of this value between the three regions of interest, opening space for new conclusions, related to their legislation.

Statistical Considerations

With the use of the surveyed statistical methods, three considerations must be emphasized, to avoid errors and inaccurate referrals in the analysis of results obtained from the use of the Pearson coefficient.

The first, and theoretically, the most important, is the false impression that the accelerated and inattentive reading of the result of the correlation coefficient can generate that a strong correlation, close to the permitted extremes for the coefficient, implies that a variable causes another, which in fact is not true. Represented by the canonical phrase "Correlation is not Causation", this misinterpretation stems from the intentions of certain users to find causes for problems from the way they vary together, that is, they correlate, which, in most cases, do not it is true. A great example to illustrate the concept, used by Clarke [17], was the case of a supposed student who has good grades in physics and chemistry, for example. The good performance in physics cannot be explained by the good performance in chemistry and vice versa. The good grades in these subjects could be explained by the good performance in mathematics, the dedication of the student, the personal ease in learning, among other factors not considered in the first moment.

For the study of the impact and the use of correlation in recalls, therefore, it must be consider that, however much it is possible, by means of an assumption, to find high correlations between the variables number of recalls and rate of licensed vehicles, this does not mean that one is the cause of the other, it just indicates that they vary together, and may have numerous causal variables not considered in the numerical mathematical model, as is the case with legislation, which will be raised to analyze and explain the obtained values.

The second consideration to be made, in addition, is a direct consequence of the first, which is the non-sensitivity of a value obtained from the correlation to other variables not considered in the model. More concretely, this property can be described by an example of studying the impact of recalls: a supposed economic crisis affects a certain location (external causal variable), this may cause the number of cars sold to fall in the short term, it is expected that this will break the correlation between this number and the number of recalls carried out in the same period, which, in a counter intuitive way, does not actually occur, since the external causal variable is causal for both and, if it occurs an abnormal variation in one of the two sets, the other must undergo an abnormal variation as well, if both really have a strong correlation. It does also work when there is prosperous time and the number of vehicles grows, because there is more consumption. In this case, it is expected that the number of recalls grows as well, what actually happens, due to a greater flow of products, but the Pearson coefficient is good enough to bypass those extreme variations, maintaining the proportion, if both vectors have actually a strong correlation between them. In summary, Pearson's correlation does not depend on what occurs outside the model, that is, on the possible causes for the variations in the data sets, since once both are correlated, this is analyzed in an indifferent way from the outside.

In general, we can see two characteristics of Pearson's correlation index that complement each other in contrast: even though it does not indicate the causality between two groups of variables, it also does not suffer from causal variations to obtain the correlation between these same two groups, allowing, for certain analyzes that may consider this information as unnecessary, to ignore the causes of the variations of the data sets for the decision making and formulation of conclusions. The latter is not the case in this study, since part of the root causes of the variations found will be inferred from legislative

differences, which Clarke [17] called “the study of misleading influence of a third variable”.

Finally, the third consideration to be made about the method to be studied is the specificity of the results found for the restriction of study time. That is, correlation results will be obtained for a given period of time, from the data available for analysis, being it between the years 2011 and 2019. From these calculations, it will not be possible to infer conclusions for the entire period of time of the occurrence recalls in history, as a non-probabilistic sample will be used and only with very sophisticated hypothesis tests would it be allowed to generalize the results to the data population (all recalls already made and yet to be made), but still, they would be extremely inaccurate conclusions, since these data sets suffer irregular variations and are difficult to propagate to other periods of time, resulting from culture, the ideology of society, among other factors of difficult mathematical measurement. In general, what this third property determines is that we will be dealing with the entire population of elements, including recalls between 2011 and 2019, and the conclusions reached will not be valid for the entire history of the recall, but only for the period of study and short-term variations, given the causes, variations and inaccuracies of a non-probabilistic sample, if taken in this way, with the population being all recalls.

Results

Presenting the methodology, its application conditions and relevant considerations for a correct interpretation of the results, it is possible to apply it to the scope of the study.

It is important to notice that NHTSA [18] and the European Commission [19] consider motor vehicles as: automobiles, pickup trucks, motorcycles, mopeds, tricycles, quadricycles, ATV, motor home, trailers, trucks, buses, tractors and special vehicles. In this work, the same classification of motor vehicles for the region of Brazil was adopted and all the data, acquired on April 2020, must be adjusted to the same base, as far as possible.

For Brazil, the first region of interest, Table 04 can be constructed, with the number of recalls that occurred, the number of vehicles affected and the number of licensed vehicles, between the years 2011 and 2019. The search was made in bodies regularized by the government and the sources are the National Consumer Secretariat [6], the Brazilian Open Data Portal [20] and the recall bulletins available on the Consumer Protection Portal [21], to obtain the number of recalls and affected cars, and the Organization of Motor Vehicle Manufacturers [22], in addition to the Brazilian Association of Manufacturers of Motorcycles, Mopeds, Scooters, Bicycles and Similar [23], to obtain the number of new licensed vehicles.

Therefore, from such data, it is possible to obtain the first and second application of the Pearson coefficient described:

$$p_1 = \frac{cov(X,Y)}{\sqrt{Var(X)\times Var(Y)}} = \frac{1.4098}{\sqrt{908.7500\times 0.0166}} = 0.3629 \quad (2)$$

$$p_2 = \frac{cov(Z,Y)}{\sqrt{Var(Z).Va\ (Y)}} = \frac{-1.5174\times 10^4}{\sqrt{6.2531\times 10^{11}\times 0.0166}} = -0.1489 \quad (3)$$

Finally, for this location, it can be discovered the third index that will be used for the analysis:

$$p_3 = \frac{p_1}{p_2} = \frac{0.3629}{-0.1489} = -2.4372 \quad (4)$$

For the second region of interest, the United States of America, the data were gathered on Table 05, with the number of recalls that occurred, the number of vehicles affected and the number of new licensed vehicles, for 2011 until 2019. The data sources were the National Highway Traffic Safety Administration 2019 Recall Annual Count [24], to obtain the number of recalls carried out and the number of vehicles affected, and the Organization of Motor Vehicle Manufacturers [22], in addition to the Motorcycle Industry Council graphs [25] and Annual Reports [26], to obtain the number of new registered vehicles over the years.

Thus, calculating the three interest rates for that location, we have that:

$$p_1 = \frac{cov(X,Y)}{\sqrt{Var(X)\times Var(Y)}} = \frac{-5.7361}{\sqrt{17123.5000\times 0.0023}} = -0.9046 \quad (5)$$

$$p_2 = \frac{cov(Z,Y)}{\sqrt{Var(Z).Var(Y)}} = \frac{-4.5467\times 10^5}{\sqrt{2.1194\times 10^{14}\times 0.0023}} = -0.6445 \quad (6)$$

$$p_3 = \frac{p_1}{p_2} = \frac{-0.9046}{-0.6445} = 1.4036 \quad (7)$$

Finally, for the third and last region of interest, the European Union, Table 06 can be constructed, with the number of recalls that occurred and the number of new registered vehicles, between 2011 and 2019. The bodies of the European Union do not provide the numbers of vehicles affected by recalls over the years, which means that this information cannot be used in this study. The sources used were the Rapex Annual Reports from 2011 to 2019 [27], to obtain the number of recalls that occurred, and the Organization of Motor Vehicle Manufacturers [22], in addition to the European Association of Motorcycle Manufacturers [28], to the number of new registered vehicles over those years.

Due to the lack of information on the number of vehicles affected by the calls, it is not possible to calculate the p_2 and p_3 indexes for that location. In addition, the p_1 index is given by the expression in equation 08.

$$p_1 = \frac{cov(X,Y)}{\sqrt{Var(X)\times Var(Y)}} = \frac{-0.8438}{\sqrt{13732.859\ \times 0.0029}} = -0.0013 \quad (8)$$

In order to facilitate the writing and reproduction of the previously obtained indexes, as well as to improve their identification, a nomenclature will be adopted so that these tasks are accomplished. Thus, the p_1 coefficient of Brazil (B), for example, will be abbreviated as given in equation 09.

$$p_1\ of\ Brazil = p_{1,B} \quad (9)$$

In the same way, the other coefficients of the same location will have the same nomenclature, except for the corresponding number. Therefore, for the United States of America, the indexes will have the addition of a letter U, initial of the region name. In equation 10, an example of this location, considering its p_1 index.

$$p_1\ of\ USA = p_{1,U} \quad (10)$$

So, finally, the European Union indexes will receive a letter E. An example, considering its coefficient p_1, is in equation 11.

$$p_1\ of\ EU = p_{1,E} \quad (11)$$

It is worth noting that the rate of new registered vehicles, obtained by the authors through the number of new vehicle registrations, considering the consecutive period, over the years, used to calculate the previous correlation coefficients, is also given in the tables, represented by (*), considering its right position in the vector Y, where x is a representation of undetermined values, due to lack of information available until the date of publication. In addition, it is important to explain an instance of how vector Y (rate of new registered vehicles) was calculated. For the Brazilian case, as an example, in 2011, this value can be calculated by equation 12.

$$Y_{2011}\ of\ Brazil = \frac{5{,}439{,}464 - 5{,}573{,}791}{5{,}573{,}791} = -2.41\% \quad (12)$$

Table 04 – Number of Recall Incidents, Affected Vehicles and New Vehicle Registrations in Brazil

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019
Number of Automotive Recall Incidents (X)	55	58	72	89	114	122	125	137	123
Number of Affected Vehicles (Z)	645,963	380,578	694,682	1,691,097	2,868,263	1,659,202	1,871,800	2,049,190	2,070,028
Number of New Vehicle Registrations	5,573,791	5,439,464	5,282,941	4,927,704	3,793,573	2,950,114	3,023,751	3,408,542	3,865,084
Rate of New Registered Vehicles (Y)*	-2.41%	-2.88%	-6.72%	-23.02%	-22.23%	2.50%	12.73%	13.39%	x

Table 05 – Number of Recall Incidents, Affected Vehicles and New Vehicle Registrations in USA

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019
Number of Automotive Recall Incidents (X)	597	582	628	771	862	919	809	912	881
Number of Affected Vehicles (Z)	13,612,039	16,486,229	20,260,042	50,032,376	49,863,794	50,138,221	30,689,022	29,455,396	38,583,951
Number of New Vehicle Registrations	13,481,513	15,245,236	16,349,243	17,326,964	18,346,324	18,352,873	18,022,034	18,158,602	17,923,392
Rate of New Registered Vehicles (Y)*	13.08%	7.24%	5.98%	5.88%	0.04%	-1.80%	0.76%	-1.29%	x

Table 06 – Number of Recall Incidents and New Vehicle Registrations in EU

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019
Number of Automotive Recall Incidents (X)	171	149	160	194	214	372	440	429	475
Number of New Vehicle Registrations	17,216,144	15,714,841	15,320,420	16,209,163	17,736,288	18,965,364	19,283,488	19,344,233	19,693,121
Rate of New Registered Vehicles (Y)*	-8.72%	-2.51%	5.80%	9.42%	6.93%	1.68%	0.32%	1.80%	x

Another possible mathematical entity that helps to visualize the points for which the correlation is being calculated is the construction of a scatter diagram. This diagram is composed by the plot of a point with the coordinates composed of the two information on which we are calculating the correlation. Graphs usually have lines, complete or dashed, and curves, but the scatter diagram does not fit into the common categories: each variable x and y are objects of great variability and, due to this, a cloud, or scatter, is obtained from points instead of a well-defined line [17].

In Figure 03, for example, we have a scatter diagram of vectors X, number of recalls, and Y, variation of new registered vehicles, of the methodology proposed previously, responsible for the correlation coefficient p_1, for the three regions of interest, between 2011 and 2018, years in which there is total available information.

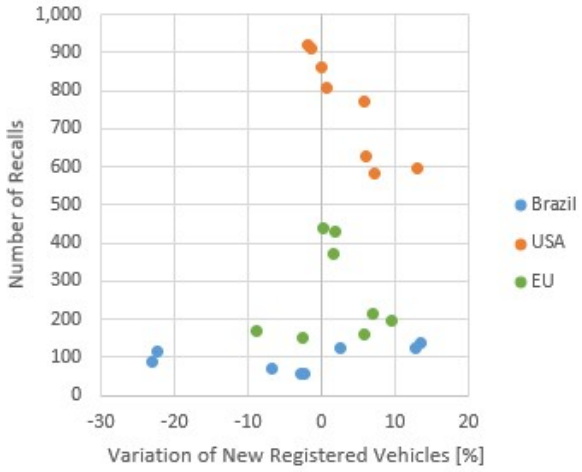

Figure 03 – Scatter Diagram of X and Y

In Figure 04, the scatter diagram is made with the vectors Z, number of affected vehicles, and Y, variation of new registered vehicles, responsible for the correlation coefficient p_2, for only two of the three regions of interest, between 2011 and 2018, years in which there is total available information.

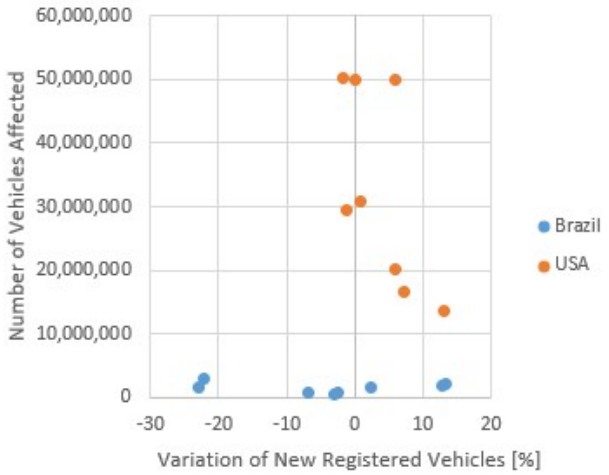

Figure 04 – Scatter Diagram of Z and Y

In addition, it is possible to plot the variation of new registered vehicles and the number of recalls through the years, on the same graph, in which there is total available information, that is, 2011 to 2018, for the three regions of interest. The graph, alongside its label, is presented in Figure 05.

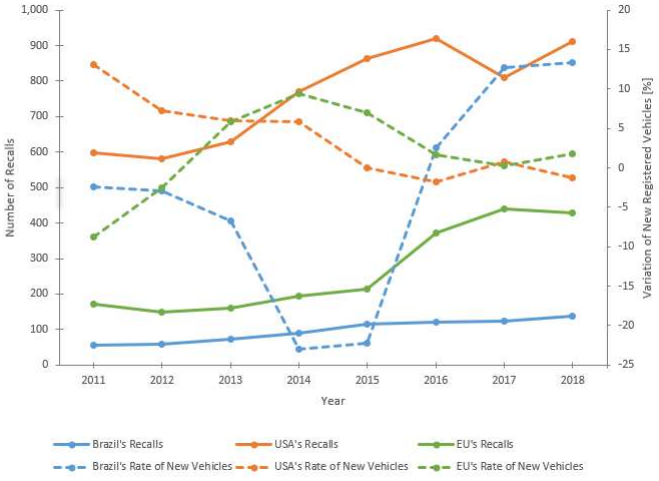

Figure 05 – Plot of X and Y through Time

To last, it is possible to plot, on the same graph, the variation of new registered vehicles and the number of vehicles affected by recalls through the years in which there is total available information, that is, 2011 to 2018, for Brazil and USA. This last graph, alongside its label, is presented in Figure 06.

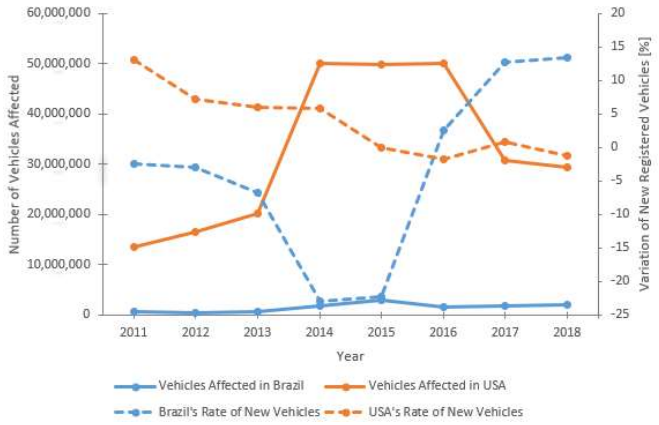

Figure 06 – Plot of Z and Y through Time

It is interesting to mention that the abnormality in the numbers of the Brazilian case, between 2014 and 2015, are consequences of the political and economic crisis that occurred in the country.

Once the coefficients for the regions of interest were calculated, in addition to the construction of the scatter diagrams and line graphs, analyzes can be made from them, considering the influence of the regional legislation and trying to infer the influence of the rules imposed on the variations and similarities of these indexes and graphics.

Discussions and the three Analyzes

The discussions and analyzes that can be extracted from the results are divided into three themes: intensities, categories (clustering) and volumes.

Starting with the intensive aspect, it can be seen, from Pearson's coefficients calculated for the three regions, that they respond differently to the number of disclosures and the intensity of those, that is, to the amount of affected products.

Brazil, the first to be exposed, has $p_{1,B} = 0.3629$, that is, when the number of recalls that happened in the country, during the years of study, has undergone considerable variations, as seen in Figure 05, the consumer's impression did converge with it, that is, both variables followed each other with a medium intensity (having seen the index with a medium value, but positive), which could take us to the observation that the Brazilian public was more inert to the variations in call numbers, even consuming more when there were a higher frequency of recalls. On the other hand, analyzing the result of the second coefficient, $p_{2,B} = -0.1489$, it can be seen that Brazilian consumers may vary their purchases less as there are variations in the total number of vehicles affected by calls, but when it happened, it was in a negative way, that is , the greater the variation in the number of vehicles affected, the greater is the opposite variation in the number of vehicle purchases by the public. Both observations could be drawn directly from the index $\mathrm{p}_{3,\mathrm{B}} = -2.4372$, since it represents the relationship between the intensities of both Pearson coefficients, and this implies representations of how the purchase of the population is related to the number of recalls and vehicles affected. Knowing that $|\mathrm{p}_{3,\mathrm{B}}| > 1$, it means that $|\mathrm{p}_{2,\mathrm{B}}| < |\mathrm{p}_{1,\mathrm{B}}|$ and, therefore, this location could be responding more intensively with the variation of the number of automotive recalls incidents than with the variation of the number of vehicles affected, but in a unexpected way, being positive convergent to the first and divergent from the second.

Next, there is an analogous analysis for the second region of interest, the USA. With Pearson's coefficient $p_{1,U} = -0.9046$ it is clear that the American consumer public could be correlating more intensely with the number of recalls than the Brazilian public, for example. Similarly, it is also observed that the public in this location also could be correlating, in a valid intensity, with the number of vehicles affected, since $p_{2,U} = -0.6445$, with the rate of new vehicles varying antagonically to the number of incidents and the impact of those incidents, represented by the number of products affected. Thus, it is expected that $|p_{3,U}|$ has a value greater than one, because $|p_{1,U,}| > |p_{2,U}|$, which actually occurs, being, finally, $p_{3,U} = 1.4036$, representing a conceivable stronger reaction, by consumers, with the number of calls than with the number of vehicles reached, that is, the impact that the recalls have.

The third place of study, the European Union, despite apparently contradicting the expectations created by the descriptions made, as it has recent legislation, has a normative explanation for its $p_{1,E} = -0.0013$. As it has recently become a block, only in 1993, and member countries maintain high legislative autonomy, it is not possible to see the 2001 Directive as the first norm to be formalized, as it does not present a result similar to the Brazilian one (in which the recent legislation leads to possible devaluations in the number of calls), since even before the definition of the law, countries already had their own rules and, even after the approval of the norm, countries continued to define national laws for the problem of defective products after being placed on the market, affecting the block's way of seeing automotive recalls.

Due to the unavailability of data by Rapex [8], it is not possible to analyze the differences in the way the local public reacts between the number of recalls and their impacts for the region during the study period.

In addition, starting with the second proposed analysis method, by categories, it is possible to observe, from Figures 03 and 04, that the recalls in the three locations have characteristics that define themselves, resulting in the formation of small clusters in the same graphs, between regions, separately. For the Brazilian case, it is possible to notice the presence of fewer recalls, less impact and greater variations regarding new vehicles registered during the years, possible result of the crisis that happened. For the second organization, the United States of America, on the other hand, recalls are more numerous, with greater total impact and smaller amplitude in the consumer response, represented by the variation of new registered vehicles, making this cluster the most aligned from the three locations studied. In addition, in the case of the European Union, it can be seen a relevant approximation of the Brazilian case, with a cluster formed just above the cluster of the first location. Finally, the EU presents recalls of average characteristics between the two locations, that is, less numerous than the American recalls, but more numerous than the Brazilian case, with a smaller range of registered vehicles than the case of Brazil, but greater than the case of the USA.

Besides that, it is known that the dispersions in the USA and in the EU are lower, because the volume of sales does not vary too much along the years, since they are composed by stable markets, without an explosive growth, but also without considerable reductions in the volume of vehicles produced. On the other hand, in the Brazilian case, the dispersion is vastest due to the unstable economic situation of the region.

Finally, a volume analysis can be done, from Figures 05 and 06, for the three regions simultaneously. This is close to the well-known fundamentalist economic analysis, since it tries to represent macro-economic panoramas from the detailed study of the conditions of each location and company, here the legislation fits, but without ignoring the ideas of a more technical graphic analysis.

Thus, from the line graphs obtained and the legislative foundations raised for each location, it can be seen that the automobile sector in Brazil shows robust fluctuations in the rate of second-degree of the number of vehicles (given by the rate of change of new registered vehicles), oscillating around 0, which culminates in lower sector growth in the region. Differently from the Brazilian case, the other two locations presented smaller variations in this rate of the second-degree, being positive in 75% of the period of years, resulting in more advantageous growth in the sector, when they occurred. Since, in order to evaluate the sector with theoretical mathematical details, a double integration analysis of this second-degree rate would be necessary, this analysis is called volume analysis (given the volumetric character of a double integration). For claims related to product safety legislation, calculations of such complexity are not appropriate (since it would be easier to see the total number of vehicles in a location, for example), but an analysis of why the last two locations have more constant indexes than the Brazilian case is. A conceivable explanation would be nothing more than the union of the last two propositions related to norms, intensity and clustering. Once the differences in intensity are exposed, a possible relationship between Brazilian consumers and the way they interpret the

automotive sector, more precisely, from the recall bias, is imposed. This relation, influenced by the local legislation, in association with clustering, also influenced by the regulations of the region, make the sector have the unique final impact, driven by crises, assessed by the volume analysis, with less positiveness growth in the second-degree rate, than compared to other locations, USA and EU, following on the rate results seen in Figures 05 and 06, culminating, finally, in the impact correlated with automotive recalls, following the Pearson coefficient models calculated for each location.

It is still possible to perceive interesting information about the number of automotive recalls. It is noticeable an increase in the number of them, seen in Figure 05, over the period studied, and this occurs mainly due to the consolidation of laws and the attention of companies with the media and communications. It is also interesting to note that a simplification of the case considered is the fact that the numbers of recalls and vehicles affected may not only depend on the previous year, since vehicles produced in one or more years ago, in relation to a reference year, can be part of a recall in that same reference year.

Finally, still as a complement, Figure 06 shows an abnormal growth in the number of vehicles involved in recall between 2014 and 2016 compared to the growth in the number of new registered motor vehicles. This fact is explained due to specific recalls that involved large quantities of vehicles in this period. In just two recalls, General Motors ignition switch and Takata Corporation airbags, a total of 71.6 million vehicles were affected, two practical examples in which the public's opinion was driven much more by the number of vehicles than by the number of recalls, given the absurd intensities of both cases. In addition to these events, another notable problem, related to the large volume automotive vehicles, is the fact that many consumers do not recall their vehicles, even though they are notified [29, 30, 31].

Conclusions

With a detailed search of the data in trusted public agencies, it was possible not only to gather the legislative history of the studied regions, but also the numbers of recalls, affected vehicles and registrations of new vehicles over the years for the three locations, Brazil, United States of America and the European Union. A possible object of discussion would be the fact that the European Union does not disclose the number of vehicles affected publicly: reasons and possible consequences of this restriction lead to considerations that could be studied in the future.

A deduction and detailed explanation was made about the application of the three analyzes for the case of local laws, but it is noticeable an opening for the generalization of the analyzes, starting with other misleading variables, consequently, broadening the analysis of the impact of automotive recalls, from the application of these three pillars. Therefore, an analytical and descriptive method is built on the impact variables of automotive recalls from the critical and detailed exposure of the normative case, for the three regions of interest. Finally, for the next work related to impact, it is necessary to apply the theory exposed to other variables, generalizing localities and expanding the method to other branches and periods of time, considering the three biases, through a possible new manner of analysis, as artificial intelligence and machine learning.

The population restrictions imposed, regarding the non-generalization of time, prevent the model, in its analytical bias, from being expanded over time. However, it is finally possible to recursively realize how the descriptive bias of the model of the three regions does not depend on the variables analyzed, that is, how the nature of the automotive recall process seen through the bias of a determined characteristic fits the model derived from it, without even a dependence on time, thus creating a timeless population idea valid for all the implications related to impact, at least in its descriptive character, the theory of the three analyzes.

References

1. Hora, M., Bapuji, H., Roth, A.V., “Safety hazard and time to recall: the role of recall strategy, product defect type, and supply chain player in the US toy industry”, Journal of Operations Management, v. 29, no. 7-8, 766-77, 2011.
2. Mackelprang, A., Habermann, M., Swink, M, “How firm innovativeness and unexpected product reliability failures affect profitability”, Journal of Operations Management, v. 38, 71-86, 2015.
3. Baraldi, E.C., Kaminski, P.C., “A study on the causes of recall in automotive vehicles marketed in Brazil”, SAE Technical Paper Series, v. 36, 1-6, 2016.
4. Eilert, M. et al., “Does it pay to recall your product early? An empirical investigation in the automobile industry”, Journal of Marketing, v. 81, 2017.
5. Silva, I., Calarge, F., Rosa, F., “O processo de divulgação de recall: as práticas da indústria automobilística e a influência na resposta do consumidor”, Exacta, v. 9, no. 2, 157-68, 2011.
6. Senacon, Secrataria Nacional do Consumidor, accessed March 20, 2020, https://www.justica.gov.br/seus-direitos/consumidor.
7. NHTSA, National Highway Traffic Safety Administration, accessed February 13, 2020, https://www.nhtsa.gov.
8. European Commission, “Safety Gate: the rapid alert system for dangerous non-food products”, accessed March 20, 2020, https://ec.europa.eu/consumers/consumers_safety/safety_products/rapex/alerts/repository/content/pages/rapex/index_en.htm.
9. Kaminski, P.C., “Desenvolvendo produtos com planejamento, criatividade e qualidade”, Rio de Janeiro: Editora LTC, 2000.
10. Schiffman, L., Kanuk, L. L., “Consumer behavior”, 7th ed, NJ, UpperSaddle River: Prentice Hall, 2000.
11. Amaral, D.C., “Arquitetura para gerenciamento de conhecimentos explícitos sobre o processo desenvolvimento de produto”, Doctoral Thesis, 2002.
12. PROCON-SP, Programa de Proteção e Defesa do Consumidor, accessed March 25, 2020, https://sistemas.procon.sp.gov.br/recall/.
13. Souiden, N., Pons, F., “Product recall crisis management: the impact of manufacturer’s image, consumer loyalty and purchase intetion”, Faculty of Business Administration, Marketing Department, Laval University, Quebec, Canada, 2009.
14. Brasil, “Lei nº 8.078, de 11 de setembro de 1990. Dos Direitos do Consumidor”, Diário Oficial [da] República Federativa do Brasil, Brasília, DF, 11 sep. 1990, accessed February 13, 2020, http://www.planalto.gov.br/ccivil_03/leis/l8078.htm.
15. U.S. Code Title 49 – Transportation 2011 Edition, 2011, accessed March 20, 2020, https://www.govinfo.gov/content/pkg/USCODE-2011-title49/html/USCODE-2011-title49.htm.
16. Taylor, R., “Interpretation of the correlation coefficient: a basic review”, Journal of Diagnostic Medical Sonography, v. 6, 35-39, 1990.
17. Clarke, G.M., Cooke, D., “A basic course in statistics”, 5th ed, JW, 2005.
18. NHTSA, “New manufacturers handbook – requirements for manufacturers of motor vehicles and motor vehicle equipment”, U.S. Government Publication, 1-68, 2014.

19. European Commission, “Vehicle categories”, accessed September 14, 2018, https://ec.europa.eu.
20. DADOS.COM.BR, Portal Brasileiro de Dados Abertos, accessed April 16, 2020, http://www.dados.gov.br/dataset/recall-campanhas-de-chamamento1.
21. DEFESA DO CONSUMIDOR, SENACON/Ministério da Justiça e Segurança Pública, accessed April 16, 2020, https://www.defesadoconsumidor.gov.br/portal/biblioteca/100-boletins/569-boletins-recall.
22. OICA, Organisation Internationale des Constructeurs D’Automobiles, “Sales of new vehicles 2005-2019”, accessed April 30, 2020, http://www.oica.net/category/sales-statistics/.
23. ABRACICLO, Associação Brasileira dos Fabricantes de Motocicletas, Ciclomotores, Motonetes, Bicicletas e Similares, “Dados do Setor – Motocicletas”, accessed April 30, 2020, http://www.abraciclo.com.br/dados-do-setor/38-motocicleta/80-vendas-varejo.
24. NHTSA, “NHTSA 2019 Recall Annual Count”, accessed April 16, 2020, https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/2019_recall_annual_count_final-031620-v1-tag.pdf.
25. MIC, Motorcycle Industry Council, accessed April 30, 2020, https://www.mic.org.
26. MIC, Motorcycle Industry Council, “2019 Motorcycle Statistical Annual Report”, accessed April 30, 2020, https://www.mic.org/#/resource-store.
27. RAPEX, “Rapid Alert System for Dangerous Non-food Products Annual Reports”, accessed April 16, 2020, https://ec.europa.eu/consumers/consumers_safety/safety_products/rapex/alerts/repository/content/pages/rapex/reports/index_en.htm.
28. ACEM, The European Association of Motorcycle Manufacturers, accessed April 30, 2020, https://www.acem.eu/.
29. Comitee on Commerce, Science and Transportation, “Danger behind the wheel: the Takata airbag crisis and how to fix our broken auto recall process”, accessed March 24, 2019, https://www.govinfo.gov.
30. Conner, S.L., Wanasika, I., “General Motors: the ignition switch from hell”, Journal of Case Studies, v.36, 66-81, 2018.
31. Eifler,T., Howard, T. J., “The importance of robust design methodology: case study of the infamous GM ignition switch recall”, Research in Engineering Design, v. 29, 39-53, 2018, doi:10.1007/s00163-017-0251-x.

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