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Scientific articles

**Educación y empleo en la industria de autos eléctricos en
México en tiempos de crisis económica**

***Education and employment in the electric car industry in Mexico in times
of economic crisis***

***Educação e emprego na indústria de carros elétricos no México em
tempos de crise econômica***

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Resumen

El propósito de esta investigación es analizar la estructura educativa de las carreras relacionadas con la industria automotriz, con un enfoque en los vehículos eléctricos, y evaluar la tasa de desempleo de dicho campo laboral durante la crisis económica desencadenada por la pandemia de covid-19. La metodología propuesta implica la aplicación de una regresión econométrica múltiple utilizando series de tiempo e incorporando una variable *dummy* para cuantificar el impacto de la crisis económica en el empleo dentro de la industria de vehículos eléctricos. Los resultados preliminares sugieren una reducción significativa en el empleo dentro de esta industria durante la crisis económica.

Palabras clave: industria automotriz, vehículos eléctricos, empleo, educación.

Abstract

The electric vehicle industry is a component of the automotive industry, and this a part of the manufacturing industry. An automotive engineer is a specialist in the design, manufacture, and operation of all the systems that ensure the proper functioning of motor vehicles. The objective of this research is to analyze the educational structure of the careers related to the automotive industry with an emphasis on electric vehicles, as well as to measure the unemployment rate of this industry during the economic crisis generated by COVID-19. The methodology proposes to apply a multiple econometric regression using time series integrating a dummy variable to quantify the effect of the economic crisis on employment in the electric vehicle industry, where the previous results indicate a considerable reduction in employment in this industry.

Keywords: Automotive industry, electric vehicles, employment, education.

Resumo

O objetivo desta pesquisa é analisar a estrutura educacional das carreiras relacionadas à indústria automotiva, com foco nos veículos elétricos, e avaliar a taxa de desemprego dessa área de trabalho durante a crise econômica desencadeada pela pandemia de covid-19. A metodologia proposta envolve a aplicação de uma regressão econométrica múltipla utilizando séries temporais e incorporando uma variável dummy para quantificar o impacto da crise econômica no emprego na indústria de veículos elétricos. Os resultados preliminares sugerem uma redução significativa do emprego nesta indústria durante a crise econômica.

Palavras-chave: indústria automobilística, veículos elétricos, emprego, educação.

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Introduction

The concept of work, as stated by Smith (1958), is fundamental in the economy, since it is the main means through which goods and services are produced, hence this author describes it as “the background that in principle it provides it with all the things necessary and convenient for life, and which the country consumes annually. Said fund is always integrated either with the immediate product of work, or with what is purchased from other nations through said product” (p. 3). In this sense, work is the real measure of value in the exchange of goods and services.

However, in the dynamics of the current labor market, coordination problems are perceived between companies, which demand specific skills, and the supply of labor by



workers. This discrepancy is largely due to the time gap between the new technical demands of companies and the adaptation of study plans in universities, which is especially evident in sectors such as the electric car industry, since Traditional automotive engineering curricula continue to focus on internal combustion engine vehicles, with little attention to electric vehicles.

Therefore, according to Rehem and Brinsco (2021), today's labor landscape requires an adaptation in both educational training and employment policies to guarantee greater correspondence between the skills acquired and those demanded by the current labor market. Employability refers to the convergence of elements related to the formation of human capital in order to satisfy the needs of organizations regarding the labor of their workers (Moreno, 2015). This implies establishing a beneficial relationship between human capital and companies to generate added value in the production of said companies.

However, employability does not depend only on the worker, but also on factors such as market needs, the employer's preferences, the description of the vacancy or the individual characteristics of the worker (Beck - Genshein , 2002). In other words, employability is a complex concept that encompasses both macroeconomic and microeconomic elements that must be taken into account to understand the causes of unemployment (Llinares *et al .*, 2016).

For example, the demand for professionals in the labor market can be affected by factors that are sometimes unpredictable, which usually impacts the reduction of its operations and investments and, therefore, a decrease in the hiring of personnel.

For this reason, the objective of this research is to analyze the educational structure of public and private universities that offer careers related to the automotive industry, but with a focus on electric vehicles. In addition, it seeks to determine the level of impact that the economic crisis had on employment within this industry through a multiple econometric regression to project the rate of decrease during the covid-19 crisis.

The article is organized into five distinct sections. The first section is dedicated to presenting the theoretical-conceptual framework, which introduces the reader to issues related to the labor market, employability and the nature of work itself. The following sections delve into education linked to the automotive and electric vehicle industry in Mexico, as well as the identification of the geographic areas where this industry is developed within the country. Subsequently, the methodology used is explained in detail and, finally, the results obtained and the conclusions derived from the research are offered.

Theoretical-conceptual framework

Employability

Employability refers to the ability of a worker to fill a job vacancy and meet the expectations of a job, therefore it implies a set of skills and tools that a person possesses to meet the needs of a specific position in the workplace. working market. According to Neffa *et al.* (2000), employability refers to “the probability that unemployed people have of finding a job in a given period” (p.27).

On the other hand, the labor market is a term composed of two elements: *market*, which is the physical or virtual place where suppliers and buyers meet to carry out purchase and sale transactions, and *labor*, which refers to the work itself. Therefore, the labor market includes both companies that demand workers and people willing to offer their work.

For Suárez (2016), employability represents a direct relationship between education and work, where professionals tend to obtain and maintain employment through synchronization with the labor market that allows them to find jobs in accordance with their abilities. In this context, employability competencies include skills such as emotional intelligence, effective communication, leadership and conflict management, among others, that allow the worker to function effectively in their work environment.

Finally, regarding the manufacturing industry, including the electric car industry, it has been observed that employability reacts significantly to changes in salary, with inverse movements in the level of labor used (Cerrato Reyes *et al.* . 2016).

Job skills

The concept of *labor competence* emerged in the eighties in industrialized countries as a response to the problems of coordination between the educational and business systems due to the need to train human resources that were in tune with the requirements of companies (Mertens , 1996) . .

In addition to the above, the constant evolution of business structures has transformed the conception of work, which has led to changes in the form and requirements of jobs. Therefore, currently, greater importance is given to technical knowledge and work skills that contribute to the continuous improvement of the organization, which leads to a trend towards labor flexibility.

Likewise, technological change and productive restructuring in organizations have caused a shift from a workforce based on qualifications to the demand for skills. In other words, companies value accumulated experience and the set of skills acquired in the work environment more than pure academic knowledge. Consequently, it is

recognized that the competencies developed through work experience have a significant impact on company performance.

Competencies are defined as the set of human capabilities that allow innovation in the work environment, making use of experience. In other words, competencies are knowledge applied to solve complex problems in a specific work context, which requires certain skills and abilities. According to Montoya *et al.* (2007), work skills are closely related to the productive improvement of companies, which makes them an essential tool to increase the productivity and competitiveness of any organization.

On the other hand, neoclassical authors such as Theodore Schultz (1961), Gary Becker (1969) and Jacob Mincer (1974) maintain in labor economics that the heterogeneity of workers is not only due to genetic factors, but also to studies and the preparation that each individual invests in himself to improve his qualification. This perspective agrees with the idea of improvement through competencies, which has been discussed in the previous paragraphs.

Employment theory

The theory of employment, based on classical postulates, considers work as another commodity in the labor market, whose payment is determined by a salary. According to this perspective, salary is flexible and can fluctuate both up and down. This means that the amount of employment available is influenced by wages, since if there is a high percentage of unemployment, wages will not only tend to decrease, but it will also attract more workers to the labor market, who will be willing to offer their services for an even lower salary.

From the classical perspective, the labor demand curve represents the set of companies that require workers to complete their production processes. That is, a reduction in wages will increase the demand for labor, which will be reflected in greater employability. On the other hand, the labor supply curve represents workers willing to offer their labor at a certain wage level, so as wages increase, workers will be more willing to offer their labor.

However, Keynes (1981) criticized this classical view by arguing that a decrease in wages would not necessarily lead to an increase in the level of employment. According to him, increased employment could only be achieved through an increase in economic investment, and not simply through wage adjustments. In other words, the volume of employment demanded by companies is determined according to the profits they expect to generate from their operation, that is, according to the premise of minimizing costs and maximizing profits. For Keynes, therefore, the employment rate is related to the expected

profits of entrepreneurs, a concept that he calls the *aggregate demand function*, that is, the amount of employment offered based on the profits obtained by the worker (Keynes, 1981). Keynes's general theory of employment, therefore, is based on the principle of effective demand, which implies that an increase in the level of employment will increase aggregate supply, which in turn will stimulate aggregate demand.

Later, the Austrian economist William Phillips (1958) questioned the relationship between wages and the unemployment rate, arguing that unemployment is the result of an imbalance in the market and that it can only be corrected through adjustments in the nominal wage. Later, Paul Samuelson and Robert Solow (1960) tried to relate unemployment to the general price level, so they introduced the idea of a constant margin to the wage cost per unit produced.

Theory of unemployment and unemployment

Classical theory addresses the general issue of unemployment by defining two types: forced and voluntary unemployment. The first occurs when a worker becomes unemployed due to a layoff, while the voluntary occurs when the worker chooses to remain unemployed because he cannot find a job that offers equal or greater remuneration than what he had in his previous job.

According to classical theory, an increase in unemployment leads to a reduction in wages. This benefits companies, since they reduce their costs, which in turn encourages them to increase their workforce by creating new positions. In simple terms: an increase in unemployment leads to a decrease in wages, which increases company profits and therefore stimulates job creation. Consequently, unemployment is reduced and balance is restored (Lerner, 2013).

However, the arrival of the economic crisis led Keynes to object to the idea that reducing wages could justify an increase in employment. Keynes argued that a decrease in wages would not necessarily lead to an increase in the demand for labor, and that only a reduction in marginal costs, brought about by a decrease in wages, would result in a decrease in the prices of manufactured goods. For Keynes (1981), equilibrium would only be achieved if prices decrease at the same rate as wages, which means that there would no longer be any incentive for companies to increase their workforce. This contribution by Keynes marks a significant change in current dominant economic theory.

Education related to the automotive industry and electric vehicles in Mexico

Electric vehicle production areas in Mexico

The automotive industry in Mexico stands out as one of the most dynamic within the manufacturing industry as a whole, since, in recent decades, it has experienced a notable increase in vehicle production and, as a result, in its exports. Currently, Mexico has become one of the main development centers for the automotive industry, driven by the growth in attracting foreign direct investment (FDI) through the installation and operation of transnational assemblers and auto parts production plants (Gachúz , 2011).

At the beginning of the 21st century, China emerged as the largest vehicle exporter in the world and managed to position its brands around the world. Mexico has been no exception, as it is currently home to automotive companies such as BAIC and JAC. This presence has had a positive impact on the automotive sector in terms of investment, job creation and infrastructure development, which has contributed significantly to the increase in the productive capacity of said sector in Mexico (Gachúz and Montes, 2020).

In fact, BAIC has its plant located in the State of Veracruz, where it produces both conventional internal combustion vehicles and electric vehicles, while JAC is located in the State of Hidalgo, where it is dedicated exclusively to the production of electric vehicles in its plant. Furthermore, at the beginning of 2023, the transnational TESLA confirmed the installation of its new factory in Mexico with an investment of 5 billion dollars for the production of electric vehicles, which will make it the largest in the world in its category (TESLA , 2023).

Another world-renowned automaker present in Mexico in the manufacturing of electric vehicles is FORD. Its plant, located in the State of Mexico, has been producing the Mustang Mach-E model since 2020, which is the brand's first electric SUV. Last but not least, it is worth mentioning the ZACUA brand, a Mexican company based in the State of Puebla, which since 2017 has been manufacturing the MX2 and MX3 car models, also electric.

Employment during economic crises

Employment is a crucial indicator to understand the phenomena of the economic cycle, especially in times of economic crisis, which has been the subject of numerous research due to the increase in unemployment that it entails. For example, during the 2009 crisis, approximately 50 million jobs were lost worldwide, while in Mexico, in just one month of that year, the loss of 1 million jobs was reported, leading to rates of unemployment of 5.6% (INEGI, 2009). Similarly, the economic crisis of 2020, triggered



by the Covid-19 pandemic, also brought alarming figures, with an unemployment rate of 4.7% for that year (Samaniego, 2020).

Generally, unemployment during an economic crisis mainly affects low-skilled jobs, that is, those that require a workforce with low levels of education and training. These, therefore, usually have low productivity and are strongly linked to fluctuations in demand, which often leads to temporary hiring. However, it should be noted that as the economic crises continue, their consequences also begin to manifest themselves in the layoffs of highly qualified workers (Rocha and Aragón, 2012).

Investment and development in education

For Ivanova *et al.* (2020), the term *research and development* (R&D) refers to the activities carried out in the field of engineering sciences in order to increase production and, consequently, sales in order to generate greater income for companies. Logically, R&D is not an exclusive concept of companies, but also implies the participation of universities, which have the responsibility of generating knowledge through the scientific method in areas such as basic science, technological development and creation of innovative products and processes.

Several studies on learning in education, such as that of Becker (1969), highlight the crucial role of education as a driver of development. This author argues that performance rates in education are determining factors for the growth of countries, since human capital becomes an indispensable element for economic and social progress.

Additionally, Ivanova *et al.* (2020) refer to the concept of *smart specialization*, which they define as “the collaboration of several actors, mainly companies, higher education and research institutions, and other public entities, to reinforce patterns of scientific, technological, and industrial specialization while identifying and encourages the emergence of new areas of economic and technological activity” (p.132), a fundamental aspect for the comprehensive development of a nation.

Taking China as an example, Zhou and Zha (2010) state that education plays a crucial role in the evolution of science and technology in this country. An example is universities, which play a central role as trainers of professionals, who in turn drive economic development. In short, there is a close relationship between academia and the productive sector to promote the progress of nations.

Main careers related to the automotive industry in Mexico

The first electric vehicle was created in 1834 and its commercialization began in 1852, although it only lasted a few years on the market due to the lack of electric batteries. It was not until the end of the 19th century that batteries were invented by Gaston Plante and Camille Faure, which promoted the development of the electric car and positioned it as an alternative to internal combustion cars.

According to McConnell *et al.* (2007), the requirement of professionals by companies is determined by the demand for the products or services they offer, which is based on the value of the good produced. Therefore, if the work of a highly trained professional is highly productive in the organization's main activity and this activity is valued in the market, the demand for work for that professional will be high.

In the automotive industry dedicated to the manufacturing of electric vehicles, the employment of educated and qualified labor is crucial for its growth. Therefore, it is essential that vocational training programs integrate the development of technical skills and knowledge that are aligned with advances in the field. Although there are currently few specific programs focused on electric vehicles, this holistic knowledge is taught within careers such as automotive engineering. Some examples of these engineering are the following:

- The TEC of Monterrey offers a degree in Electrical Engineering/Electronics and Communications, which includes the subject of electric and hybrid vehicles in its curriculum. This advanced level course aims to provide the foundations and methods necessary for the design of vehicles powered by alternative energy sources. Upon completing the subject, students will be able to understand the methods for the design of hybrid and electric vehicles, since they address aspects such as energy sources, batteries, motors, mechanical systems and transmissions (Tecnológico de Monterrey [TEC], 2023).
- The University of Monterrey offers the Automotive Engineering degree, which includes the subject of electric and hybrid vehicles. In this, engineering students will learn to apply different electronic control and energy management configurations in electric and hybrid vehicles. In addition, they will be able to calculate and measure the main performance and operating parameters in both types of vehicles, based on analysis of cargo management centers, charging systems and energy supply systems (University of Monterrey [UDEM], 2023).

In addition, there are educational programs specialized in electric and hybrid vehicles offered by different institutions:

- Masare Motors offers the online Technical Specialist in Electric and Hybrid Vehicles diploma. According to the institution, both electric and hybrid cars are gaining ground over internal combustion cars around the world. These vehicles are considered an option to address the current environmental crisis and move towards transportation sustainability (Masare Motors, 2023).
- The ISIMA Group has been teaching the Master's Degree in Hybrid and Electric Autonomous Vehicles since 2020, which is offered online and has official recognition of RVOE studies. This master's degree focuses on developing skills to actively participate in companies in the automotive industry, so it focuses on areas such as the calculation and design of mechanical elements, electrical and electronic circuits related to hybrid and electric vehicles (ISIMA, 2023).
- Finally, the Polytechnic University of Querétaro (UPQ) has a laboratory specialized in electric vehicles, which is dedicated to the training of technical professionals linked to the electric vehicle industry, as well as the development of new technologies for this industry. Its objective is to promote productive chains related to the manufacturing of electric vehicles, with a main focus on the United States and Canadian markets (Polytechnic University of Querétaro [UPQ], 2023).

Methodology

The methodology used was based on an empirical approach through multiple econometric regression, which considers three main variables. The first is employment in the automotive industry, the second represents time (expressed in months), and the third is a binary qualitative variable that captures the effect of the crisis generated by covid-19.

Assuming that an automotive engineer can work in both the electric vehicle and conventional internal combustion engine industries, it is not necessary to make distinctions between workers employed in both industries. Therefore, to analyze the employment behavior in the electric vehicle industry during the economic crisis generated by Covid-19, the set of workers employed in the automotive industry as a whole was used as a basis.

The proposed econometric model is expressed as follows:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + u$$

As

Y = Personnel employed in the automotive industry. This variable represents the total number of workers employed in the manufacturing of automobiles and trucks, sector (336) manufacturing of transportation equipment and subsector of activity (3361) manufacturing of automobiles and trucks.

X_1 = Time measured in months, from January 2018 to May 2023 (total = 65 months).

X_2 = *Dummy quantitative variable* , 1 for the time of the economic crisis caused by the covid-19 pandemic and 0 for no.

The variables used were obtained from the Monthly Manufacturing Survey (EMIM), available in the Economic Information Bank (BIE) of the National Institute of Statistics and Geography (INEGI) (2022). This survey provides fundamental information on the current behavior of the main economic variables of the country's manufacturing sector. Data classification is carried out according to the North American Industrial Classification System (NAICS).

Results

To obtain the results, a multiple regression was run (see table 1).

Table 1. Multiple regression model to determine the employment growth rate in the industry and the effects of the economic crisis due to covid-19

Variable	Coefficient
Constant (C)	98,148***
Time (X_1)	93***
COVID-19 (X_2)	-1,426***

$R^2 0.6306$

Note: ***significant at 10%, **significant at 5%, *significant at 1%.

Source: Own elaboration in E- views based on EMIM (2018-2022)

The intercept (the point of origin), that is, the constant C , indicates the starting value, since this quantity is autonomous from the other variables. Therefore, when all the variables are worth 0, Y will be worth 98,148 employees ; In other words, the automotive industry begins with favorable conditions in terms of employability.

Regarding the **variable** *_ paribus*).

On the other hand, **the** variable

From Table 1 we can see that the value of the R-squared = .6306, so in general terms we can infer that the model fits to a good extent.

Discussion

Education plays a crucial role in the development of the electric vehicle industry, given its highly technological nature that demands specialization to address challenges at all stages of the production chain, from design to operational implementation of systems that ensure the optimal functioning of these vehicles.

After an exhaustive analysis of the main public and private universities in Mexico, the absence of specialized engineering in electric vehicles is observed, unlike what happens in developed countries such as the United States, since in this country there are educational institutions, such as Atlantic International University, offering bachelor's and master's programs in electric vehicle engineering, among others. This panorama highlights the need for Mexico to expand its educational offering in the field of electric vehicle engineering to boost the growth of this sector in the country.

Likewise, the results of the research indicate a marked growth in the employability of the automotive industry in Mexico until 2020, characterized by a period of expansion. However, the economic crisis triggered by the Covid-19 pandemic caused a reduction in the workforce, so it was not until 2022 when the economy was reactivated and companies began hiring staff again.

As Castillo and Ivanova (2023) point out, another sector affected by the crisis was the aerospace industry, which also experienced a decrease in its production due to the spread of covid-19 and the implementation of restrictive health measures to contain the pandemic, which generated a simultaneous reduction in employment in this industry. In summary, the economic crisis generated by covid-19 had negative impacts on the world economy, since it affected industrial sectors with a high degree of technological development, such as aerospace and automotive.

Conclusions

Economic history has taught us that the market is incapable of regulating itself. Therefore, to increase employment in the automotive industry following Keynes' formula, it is necessary to increase the variation in the volume of investment in this industry, although this can only be achieved based on two main options: firstly, through decreasing the passive interest rate and, secondly, increasing foreign direct investment. In addition, there is a third option that works indirectly: increasing consumption, that is, selling more electric vehicles. This option will generate a need for companies to increase their production, which will lead to greater hiring of workers by increasing installed capacity. Likewise, to expand employment, supply can be improved through the development of

job skills and employability, which represents an opportunity and a challenge to improve labor relations in the electric vehicle sector.

In short, as we have seen, the employment dynamics in the automotive complex have benefited from the entry of highly specialized people. Furthermore, it has been interesting to analyze the impact of covid-19 on the reduction in the number of jobs in this sector, in a context where the labor market experienced a contraction with the total loss of 1,426 jobs per month during the crisis. of the pandemic, which translates into a total of 17,112 jobs lost per year during the crisis.

Future lines of research

Although this research analyzed and quantified the job losses that occurred in the automotive industry as a consequence of the economic crisis generated by covid-19, this study could serve as a starting point to replicate the research in other industries, such as textiles, food, petrochemical, among others. A comparative assessment could then be carried out to determine which sector was most affected by the economic crisis.

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