

# Quantitative Analysis of The Simultaneity in Technological Innovation in The Colombian Industry Towards the Industry 4.0 Period 2007-2016.

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## Abstract

The industrial revolution 4.0 described in the economic forum of 2001, gives to the academic context and the real sector an identification based on the great changes in the industry, its identification oriented to the digitalization and more the one used in the industrial sector makes that researchers, committees of research and investigators consolidate the concept of Industry 4.0, that emphasizes more the industrial revolution 4.0, in the context of technological innovation in the industry. In this way, an analysis of innovation and technological development in Colombian industry was carried out under consultation of secondary information in a period of ten years 2007 to 2016, in which investment variables were taken into account against income benefit variables for the industry, to have an explanation against the need for investments in innovation and technological development of advanced technologies in the context of Industry 4.0, as initial classification information of types of innovation variables and technological development actions that are reflected in percentages of investment in digital technology as an input to the context of the development of industry 4.0 in the Colombian context.

## Keywords

Innovation and development, technological adaptation, Industry 4.0, correlation, simultaneity.

## 1. Introduction

The state of development of the industry 4.0 in the Colombian industry and in relation to the investigation of different groups of the academy does not offer relevant information is that on the adoption of more advanced technology in the industry, this way it was explored by information that characterized the industry of Colombia where it was found the survey realized by the national administrative department of statistics DANE Survey of Development and Technological Innovation - EDIT- Industry realized in the period 2006-2017(DANE, 2010)(DANE, 2012)(DANE, 2014)(DANE, 2017)(DANE, 2019), which is carried out every two years with a collection of information to more than 7786 companies of different sizes and different economic sectors with a proportional sample atom in the different territories of the Colombian State, with data from 2007 household to household and a battery of questions under the innovation methodology, methodology that is given worldwide to follow innovation and development of the industry in different countries. Among the promoters of information technologies (ICT) in Colombia, we found the compilation of the international observatory ITU World Telecommunication, an agency of the United Nations, from which we extracted relevant data measuring development in Colombia in the period 2007-2016 (Trends, 2019).

In the analysis of the data and its evolution in the period 2007-2016, a year-to-year correlation analysis was performed to identify six variables that characterize information technologies with a level of correlation and simultaneity with the variables classified as income from goods or services, new or significantly improved for the company, and others for the national and international markets. An analysis of the data was carried out through a statistical correlation between variables that characterize the income from new or significantly improved goods or services for the company, and others for the national and international markets, with each two investment variables related to research and development, such as internal and external activities, acquisition of machinery, acquisition of ICT, innovation marketing, technology transfer, technical assistance, specialized training, biotechnology, and total investment.

An analysis was conducted with data from an official source with ten years of collection to identify in the home what relationship exists between the investment front of Colombian industry about the benefits of income from goods or services that improved significantly in the period from 2007 to 2016, as a diagnosis of the state of Colombian industry in the context of the entry and adoption of new advanced technologies identified from the digital industry and recognition as industry 4.0.

### 1.1 Objectives

To propose a method for analyzing information from the Surveys on Technological Development and Innovation in Colombian Industry for the period 2007-2016, to identify investment variables, impact on sales, their sources, correlation and determination coefficients among them, as an input for decision making in the context of industry 4.0.

## 2. Literature Review

The principles of Industry 4.0 are interoperability, virtualization, decentralization, real-time capacity, service orientation, and modularity (Shastri et al., 2015). Industry 4.0 can be summarized as an integrated, adapted, optimized, service-oriented, and interoperable manufacturing process, which correlates with algorithms, big data, and high technologies (Kosacka-Olejnik & Pitakaso, 2019). For the World Economic Forum, information technology is at the heart of broad democratization of innovation, according to the publication of the Future of Employment (ITU WTID, 2018).

In technology adaptation, Davies et al., (2017) describe that new systems in the development of products and services will be established will be individualized, with open innovation approaches and product intelligence, as well as product memory. In this way the transformations that the productive processes of this century face are simply "changes" or constitute in effect a new technological "revolution". (CEPAL, 2018). Information technology for the world economic forum is a nucleus for the democratization of innovation (World Economic Forum, 2020). The state of adoption of advanced technologies in the industry has several international organizations that conduct exercises as observatories of companies such as Deloitte, PwC (PriceWaterhouseCoopers), Logicalis three among others where in different methodologies consult organizations in recent years to understand the impact and difficulties that arise for the adoption of advanced technologies (PricewaterhouseCoopers, 2017).

Regarding technological innovation Samylina et al ( 2019) claim that the interaction of clusters of companies and organizations of various forms of ownership gives them the necessary flexibility based on the principles of combining partnership and competition and contributes to the formation of more harmonious relationships in the transfer of information, knowledge, and technology. Within the technological innovations for (Rockel, 2019) the Internet has enabled the emergence of new markets and complete changes in business processes, from product development to the acceleration of business processes, their outsourcing, and the emergence of new markets.

For the report on emerging technologies, the organization has carried out Logicalis Group (2019) describes how the adoption of advanced or emerging technologies to drive business innovation is a major driver for companies, with perceived business benefits being the main driver according to half (50%) of respondents. However, despite large-scale testing and use of advanced technologies, many organizations do not realize the benefits in some business areas according to our survey. The results reveal that 61% of organizations now use the Internet of Things (IoT) technologies, while 41% of respondents have implemented AI in some way - twice as many as our 2018 survey.

For the development of this research, the theory of the correlation coefficient was used, as the numerical data between -1 and 1, where the values close to 1 represent the simultaneity of the behavior of the pair of compared variables. The values close to -1 indicate that the increase in one of the variables implies the decrease in the other variable. Values near 0 indicate independence or theory of behavior between the pair of compared variables. Given the variables x, y, and z, we define the multiple correlation coefficient, as described in formula 1:

$$R_{z,xy} = \sqrt{\frac{r_{xz}^2 + r_{yz}^2 - 2r_{xz}r_{yz}r_{xy}}{1 - r_{xy}^2}}$$

Equation 1 Multiple Correlation Formula.

The subscripts are eliminated and the multiple correlation coefficient and the multiple determination coefficient are simply written as  $R$  and  $R^2$ , respectively. These definitions can also be extended to more than two independent variables. With only one independent variable, the multiple correlation coefficient is simply  $r$  (Gujarati D, 2010). Unfortunately,  $R$  is not an unbiased estimate of the population's multiple correlation coefficient, which is evident for small samples. A relatively unbiased version of  $R$  is given by adjusted  $R$  (Lütkepohl & Kratzig, 2004).

Since these data, to be consolidated, require the monitoring of the instruments designed and with scope to different organizations in different countries that allow relevant descriptions of the adoption of advanced technologies in the industry, in this way are described of the international companies that carry out these exercises and have relevant conclusions to the addition of technologies in different industrial and economic sectors (Crepon et al., 1998). Now, given the projected concentrations of populations in the world whereby 2050, two out of three people are likely to live in cities or other urban centers, according to a new United Nations report, which highlights the need for more sustainable urban planning and public services (Deloitte, 2020). This population growth projects increasing demands for challenges to meet the needs of its growing urban populations, including housing, transportation, energy systems and other infrastructure, and other needs such as technology.

In the Colombian context, there are sources of information composed of institutions from which important data can be deduced. The Ministry of Information Technology MINTIC (2017) conducted the first major survey of Information technology in conjunction with the administrative department of statistics in 2017, among the micro, small and medium industry only by the way has a website, but the most important figures to consider are those related to mobile applications where only 7% have applications, and as for information systems such as ERP only 15% have these information systems.

In the analysis of the context of the evolution of the adaptation of advanced technologies in the industry 4.0 in the global context, there are results of other investigations that show figures like the following; Surprising technological statistics for small companies where 27% of the small companies do not have IT support (McCabe & Aggarwa, 2020). 53% of medium-sized companies have a website (MINTIC, 2018). Banking and securities spent 7.16% of their budget on IT, the most of any industry, while construction spent less, 1.51 (Khalid et al., 2017). 66% of small businesses would fail without wireless (Afolabi et al., 2018). 66% of small business owners rely on mobile devices to manage operations (Afolabi et al., 2018). 79% of small businesses in Colombia use cloud services (MINTIC, 2018). Cloud solutions reduce the workload of small businesses by at least 42% (Muñoz Núñez, 2019).

The supply and demand of digital services reflect the level of maturity and technological adaptation of the industry, which is why the studies of CEPAL (2018) describe the largest supply of digital services in the world as in North America with more than 3.3 billion dollars, followed by Asia with a supply of more than 855 billion dollars, in the case of Europe, a supply of 128 billion dollars and applies with a supply of 34 billion dollars and the region with the lowest supply of digital services and South America with thirteen billion dollars, reflecting a low adoption of advanced technology in the industry of the Latin American region. As for North American demand, it has a demand of 59% of digital services, Asia and Europe as 48%, but the Americas have a demand of 45% of digital services, which identifies the lack of capacity to provide more digital services solutions of the same industry in the region, which also allows defining the need for the industry to adopt advanced technology in the context of the 4.0 industry (CEPAL, 2018).

The data used are mainly taken from the DANE survey on technological development and innovation in the manufacturing sector. The EDIT is developed under the methodological guidelines developed by the Organization for Economic Cooperation and Development (OECD), especially the Oslo Manual, and by the Ibero-American Network of Science and Technology Indicators (RICYT), in the Bogotá Manual with adaptations for Colombia.

The statistical indicators presented below are developed for industrial companies that have establishments with 10 or more people employed or with an annual production equal to or greater than \$137 million (2016), annually for the period 2007-2016 corresponding to the business directory of the Annual Manufacturing Survey (DANE, 2018).

In business innovation, it is relevant to take into account the typologies established by the Oslo Manual (Palacio et al., 2017). According to the typologies are identified:

- Innovative companies: companies that have carried out technological innovations that are divided into innovative companies in the strict sense: those companies that obtained at least one new or significantly improved good or service in the international market.

- Innovative companies in a broad sense: at least one new or significantly improved good or service in the national market or a new or improved good or service for the company, or that implemented a new production process or a new form of organization or commercialization.
- Potentially innovative companies: had not obtained any innovation in the reference period; but reported having been in process or having abandoned some innovation project (Palacio et al., 2017).

### 3. Methods

An analysis of the consolidated information in the different information takes of the Survey of Development and Technological Innovation to the Colombian industry was established, identifying the variables of interest of investment made in the industry, comparing it with the results in the percentages of increase in the different methods of sales. A matrix of the information was consolidated with 6 variables of the results in percentages of increase in sales. Ten different variables of investments in innovation and development made in the industry were identified and three variables where the sources of financing were classified.

The survey developed by DANE on technological development and innovation in the manufacturing sector carried out within the framework of public policies aimed at generating economic growth, social inclusion, and sustainable development, is taken. It is essential to have the best statistical information available to serve as input for decision-making. In this context, the statistical information that gives an account of the progress of innovation and technological development in Colombia, where samples are taken for the period from 2007 to 2016, 10 years in which variables such as:

- Percentage of the company's national sales corresponding to innovations obtained.
- Distribution of the total amount invested by the companies in scientific, technological and innovation activities, according to funding sources, in each year of the reference period.
- Distribution of the amount of public resources invested by companies in scientific, technological, and innovation activities, according to lines of co-financing, in each year of the reference period.
- Distribution of the number of public resources invested by companies in scientific, technological, and innovation activities, according to lines of credit, in each year of the reference period

We identified the results presented by the companies classified in the sales represented in these, classified in new or significantly improved goods or services for:

- The company Percentage for domestic sales and export sales.
- The international market Percentage of national sales and export sales.
- The domestic market Percentage of domestic sales and export sales.

The proposal allows for the study of several interrelated issues and at the same time controls the simultaneousness in the relationship between technological innovation in the Colombian industry and sales performance (endogeneity). It is established in three stages:

- The first treatment, the correlation coefficient between investment variables and established sales results is established.
- The second treatment, the coefficient of determination of the variables treated in step one is established.
- A third treatment, the levels of the coefficients of determination against the investments established in the variables of the technological innovation in the Colombian industry are identified.

### 4. Data Collection

The selection of data is from a survey of 7786 companies representing the different types and sizes of Colombian industry, a methodology established by the National Administrative Department of Statistics, in surveys developed every 2 years, but with information from each year, to a total of 507 different data, that is, each survey has 3,947,502 data, which at 10 years is more than forty million data. Of these, only 10 questions were selected for investment amounts, 3 for financing sources, and 6 for percentage increase in sales each year. From this information a matrix was consolidated with the totals of the 19 variables taken in the 10 years, the percentages are identified in decimals, the investments per million Colombian pesos, identified in table 1:

Variables	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
New or significantly improved goods or services for the company Percentage of domestic sales	31,08	31,08	2,1E+11	2,1E+11	2,1E+11	2,1E+11	1,9E+11	1,9E+11	1,9E+11	1,9E+11
New or significantly improved goods or services for the company Percentage of sales Exports	4,39	4,39	7,2E+10	7,2E+10	7,2E+10	7,2E+10	6,1E+10	6,1E+10	3,6E+10	3,6E+10
New or significantly improved goods or services for the international market Percentage of domestic sales	14,14	14,14	13,40	13,40	13,40	13,40	10,71	10,71	2,1E+11	2,1E+11
New or significantly improved goods or services for the international market Percentage of sales Exports	18,80	18,80	7,91	7,91	7,91	7,91	7,37	7,37	3,9E+10	3,9E+10
New or significantly improved goods or services for the domestic market Percentage of domestic sales	29,85	29,85	11,74	11,74	11,75	11,75	7,07	7,07	12,45	12,45
New or significantly improved goods or services for the domestic market Percentage of sales Exports	3,84	3,84	4,69	4,69	4,69	4,69	4,42	4,42	8,57	8,57
Internal R+D activities	177,42	277,92	208,40	305,88	305,88	382,13	359,67	419,71	927,09	574,75
R&D acquisition (external)	30,19	65,11	66,90	21,44	21,44	35,74	4,46	6,62	32,95	27,89
Acquisition of machinery and equipment	2032,45	2072,05	1500,00	976,41	976,41	1362,10	779,36	1109,88	908,79	971,46
Information Technology and Telecommunications	153,98	173,78	98,09	195,01	195,01	199,51	198,62	149,47	181,49	160,03
Marketing of innovations	207,06	252,82	149,86	182,00	182,00	247,43	45,44	62,50	83,81	102,77
Technology transfer	26,13	42,38	23,37	49,84	49,84	90,65	123,01	145,50	135,27	134,55
Technical Assistance and Consulting	161,24	201,53	128,10	85,39	85,39	106,45	49,92	74,00	59,23	63,59
Engineering and industrial design	44,10	48,83	61,74	29,71	29,71	63,59	116,00	155,15	164,04	22,20
Specialized training and education	21,87	26,88	19,60	12,89	12,89	14,39	12,12	14,84	9,13	12,35
Amount invested in Biotechnology	255,35	206,52	15,10	18,52	6,30	3,74	3,92	3,57	13,65	18,13
Company's own resources	2169,42	2423,45	1781,79	1916,94	1432,20	1877,59	1400,01	1738,82	2154,53	1648,80
Resources from Other Group Companies	21,45	73,76	12,64	28,15	28,15	36,61	70,30	104,07	29,91	79,20
Public Resources	20,56	22,77	16,06	8,50	8,50	3,74	3,92	3,57	13,35	8,98

Table 1. Consolidated information from the Surveys on Technological Development and Innovation in Colombia for the period 2007 to 2016

## 5. Results and Discussion

### 5.1 Numerical Results

Thirteen variables were established from the survey of technological development and innovation of Colombian industry in the period 2006-2017, in which thirteen investment variables were selected, quantitative data of the economic amounts represented in soft and hard technology made in the industry during ten years to which a quantitative treatment was made to identify the levels of correlation with other six variables that represent the significantly improved goods and services for the companies in national sales, exports national and international market, the percentage growth of sales.

This generated 78 or results to be analyzed in which sixteen results were highlighted over 50% of the decreasing explanation and 14 results with higher levels of correlation than the non-growing percentage account, that is, the intimate results have a high level of correlation, that is, they allow to explain the influence of the amounts invested

versus the results to the industry payments, the results of this style allow to identify what could be invested if it is sought and the results of benefit both of economic goods and services for the industry as an alternative of analysis versus the industry investment 4. 0 industry in the Colombian context.

For a greater similarity, the level of significance was established when each two variables are above the non-account for hundreds of importance with a high percentage of explanation in comparison with the correlation of the two groups of variables contrasted in a simultaneity in a period of ten years that would allow establishing a projection to the following years without having investments in the variables. This would allow the identification of a high level of importance, table 2.

## 5.2 Graphical Results

Sales Amount Invested	New or significantly improved goods or services for the company Percentage of domestic sales	New or significantly improved goods or services for the company Percentage of sales Exports	New or significantly improved goods or services for the international market Percentage of domestic sales	New or significantly improved goods or services for the international market Percentage of sales Exports	New or significantly improved goods or services for the domestic market Percentage of domestic sales	New or significantly improved goods or services for the domestic market Percentage of sales Exports
	Internal R+D activities	0,47	0,10	0,81	0,81	-0,45
R&D acquisition (external)	-0,37	-0,32	-0,02	-0,02	0,53	-0,06
Acquisition of machinery and	-0,86	-0,68	-0,37	-0,37	0,89	-0,50
Information Technology and TI	0,11	0,10	0,00	0,00	-0,11	0,02
Marketing of innovations	-0,48	-0,25	-0,41	-0,41	0,66	-0,44
Technology transfer	0,45	0,15	0,57	0,57	-0,59	0,59
Technical Assistance and	-0,83	-0,61	-0,43	-0,43	0,88	-0,54
Engineering and industrial	0,22	0,08	0,20	0,20	-0,39	0,20
Specialized training and	-0,82	-0,60	-0,48	-0,48	0,81	-0,60
Amount invested in	-0,80	-0,78	-0,01	-0,01	0,84	-0,14
Company's own resources	-0,01	0,11	-0,23	-0,23	0,09	-0,20
Resources from Other Group	-0,52	-0,61	0,19	0,19	0,48	0,08
Public Resources	-0,05	-0,14	0,11	0,11	-0,17	0,06
Total amount invested	-0,79	-0,77	0,01	0,01	0,87	-0,12

Table 2. Correlation between variables of the inverted mount and variables of income from industry sales in Colombia between the periods 2007 and 2016.

## 5.3 Validation

For another analysis it also allows to identify which variables do not have relevant levels of significance, that is to say, which make need analysis why when investing in those characteristics do not reflect economic retribution and benefit of goods and services for the industry this information is also relevant to know how to classify here variable can bet more on economic investment in innovation and development, table 3.

Sales Amount Invested	New or significantly improved goods or services for the company	New or significantly improved goods or services for the company	New or significantly improved goods or services for the international market	New or significantly improved goods or services for the international market	New or significantly improved goods or services for the domestic market	New or significantly improved goods or services for the domestic market
	Percentage of domestic sales	Percentage of sales Exports	Percentage of domestic sales	Percentage of sales Exports	Percentage of domestic sales	Percentage of sales Exports
Internal R+D activities	0,205	0,011	0,525	0,525	0,189	0,559
R&D acquisition (external)	0,132	0,098	0,000	0,000	0,256	0,004
Acquisition of machinery and	0,576	0,391	0,133	0,133	0,605	0,227
Information Technology and	0,012	0,011	0,000	0,000	0,013	0,000
Marketing of innovations	0,217	0,063	0,159	0,159	0,371	0,183
Technology transfer	0,186	0,022	0,290	0,290	0,306	0,309
Technical Assistance and	0,541	0,326	0,176	0,176	0,593	0,266
Engineering and industrial	0,046	0,007	0,038	0,038	0,145	0,038
Specialized training and	0,536	0,315	0,215	0,215	0,526	0,317
Amount invested in	0,517	0,493	0,000	0,000	0,557	0,020
Company's own resources	0,000	0,011	0,050	0,050	0,008	0,040
Resources from Other Group	0,251	0,329	0,035	0,035	0,217	0,006
Public Resources	0,002	0,021	0,011	0,011	0,028	0,003
Total amount invested	0,507	0,482	0,000	0,000	0,588	0,013

Table 3. Level of significance between variables of the amount invested and variables of income from industry sales in Colombia between the periods 2007 and 2016.

In the third treatment, we classified the determination coefficients, that on average, in the period analyzed from 2007 to 2016, presented greater coefficients from greater to lesser, to identify which variable has greater determining value, comparing it to the investments made in the different variables of technological innovation in the Colombian industry.

0,354	Specialized training and education
0,346	Technical Assistance and Consulting
0,344	Acquisition of machinery and equipment
0,336	Internal R+D activities
0,234	Technology transfer
0,192	Marketing of innovations
0,082	R&D acquisition (external)
0,052	Engineering and industrial design
0,027	Amount invested in Biotechnology
0,006	Information Technology and Telecommunications
0,265	Public Resources
0,146	Company's own resources
0,013	Resources from Other Group Companies

Table 4. Levels of coefficients of determination in descending order of the 10 variables of investment in Research and Development.

The average of the coefficients of determination, allow to identify that the "Specialized training and formation" with 0.35 is the investment the greater average in the period of the 10 years, followed very near of "Technical attendance

and Consultancy" with 0.34, "Acquisition of machinery and equipment" 0.34 and "Activities of Internal R+D" with 0.33. The other variables have lower average determination coefficients. The coefficients of determination of the variables of financing sources, in general, were low; the highest among them is "Public Resources" with 0.26, followed by "Company's Own Resources" with 0.14 and the lowest "Resources of Other Group Companies" with 0.01, table 4.

A similar identification was made, but, classifying the investment sources, with their investment value and the determinant in the identified correlation.

1.268.889,578	Acquisition of machinery and equipment
376.149.112	Internal R+D activities
191.548.713	Amount invested in Biotechnology
170.498.932	Information Technology and Telecommunications
151.568.468	Marketing of innovations
101.483.912	Technical Assistance and Consulting
82.054.995	Technology transfer
73.507.035	Engineering and industrial design
31.273.143	R&D acquisition (external)
15.697.621	Specialized training and education
1.663.291.529,50	Company's own resources
48.423.952,70	Resources from Other Group Companies
10.993.938,50	Public Resources

Table 5. Declining economic investment in 10 variables on average during the period 2007 to 2016 and its sources of funding.

Having the historical information of the income and sales benefits of the industry in a survey to more than 7500 companies during ten years in their innovation and technological evolution against the investment established in the same period time in the industry allows establishing a correlation between the variables grouped as income that demonstrate a simultaneity against the investment in research and development in differentiated variables such as research and development activities, application of research and development, acquisition of material and equipment, communication technologies, technology transfer, engineering and industrial design, training and specialized training. These variables as the evidence of those invested in the context of Colombian industry to identify the correlation and simultaneity with levels of importance to identify which of these investments explains more benefits received in the industry. The discussion of this methodology will allow projecting if a willingness to invest in the identified variables is established, a benefit for the industry that invests in research and development of innovation. This is a preparation in the context of the 4.0 industry's income to the Colombian industry, table 5.

## 6. Conclusion

Using the method of analysis of the information developed, a compilation of the data of the Survey of Development of the Technological Innovation - EDIT- Industry from the period 2007-2016, I can be explained with certain levels of correlation, the behaviors of simultaneity, that is to say, of correlation between variables of investment in technological innovation, with the percentages in the sales after the investments, identifying the benefits by the surveyed companies in Colombia, this analysis is taken like an entrance for the approach of Industry 4. 0, with explanations for each of the investment items, identifying decreasing, null and increasing relationships, as a quantitative method to measure the types of investment that are more determinant with subsequent sales.

An analysis was also made of the sources of financing, identifying that the largest are investments in the same industry, but the most efficient is that of the government, given that its results are more decisive than those of other sources, and the least is that of the business groups, that is, of the supply chains in general, which identifies their weakness in the face of investments in innovation and development to strengthen the supply chains in Colombian industry with the least investment and impact.

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