5g Technology And The Economic Impact On Industry 4.0 (A Microeconomic Analysis)

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Summary

The theme of this article addresses the 5G telecommunication system available for use in society, in the industrial area and in technological advances in the production process. The connectivity provided by Fifth Generation telecommunications technology solves bottlenecks generated by industry communication services and all business sectors. This work aims to provoke a discussion about the main technical points of application of 5G Mobile technology and the Microeconomic concept in the technological advance aimed at industry 4.0. 5G will be a critical part of an enterprise's new operating environment and technology stack in the future, but to realize the potential productivity and efficiency gains that this technology can deliver, leaders need to start taking a strategic approach to implementation now, as that 5G technology is already a reality and is being tested in several nations around the world, as well as in Brazil. We know that our country, due to bureaucracy, high state regulation and low investment in research, has a considerable scientific and technological backwardness in relation to developed countries. The high regulation and bureaucracy of the Brazilian state slows down the process of technological development in our home with an impact on the productive and economic sector. We also show in this article the maturity analysis used in companies and the projection of potential GDP (**Gross Domestic Product)** until 2030.

Keywords: 5G Mobile Technology, Industry 4.0, Microeconomic

1. Introduction

This article addresses the use of 5G Mobile Technology as an aid in the implementation of industry 4.0 automation, considering the microeconomic concept and expected results. The context of the subject involves the 5th Generation of Mobile Technology (5G), the Maturity that an industry must have to implement the 4th Generation of Industry (4.0), the Microeconomic concept in production and expected results in order to put agility and functionality in business and lessen the lag in industrial development compared to developed countries.

The universalization of telecommunications services and internet access in Brazil, with the guarantee of adequate levels of quality, respect for information rights, transparency, non-discrimination and protection of personal data, in view of meeting the implementation of an industry with the 4.0 paradigm, were also considered. Thus, the series of studies involved in this work contributes to a reflection on internet access processes in Brazil, challenges and connection estimates (Idec.org 2020).

5G mobile technology presents itself as a disruptive technology, that is, very high speed, with massive connection of devices, low response time, high reliability, and the advance in the evolution of the current "Gs" of mobile telephony (2G, 3G and 4G). In this evolution, data travels at a speed of 20 Gigabits per second, equivalent to 2,500 Megabytes, in networks where a sent bit arrives at its destination in less than 1 millisecond (Idec.org 2020).

The change in the traditional business model and in the way society communicates in general has created the need to evolve the concept of wireless connectivity to the Fifth Generation of Mobile Technology (5G), in order to allow new ways of defining the monitoring and guarantee of performance, as well as the quality of service and the level of user experience. The newest generation of mobile communication provides substantial changes in the data transfer rate, in support of a large number of connected devices, in the reduction of latency time, and consequently, in the support of communications between devices in real time. It heavily uses cloud-related technologies in its core network so it can better meet demand and resource elasticity. In addition, it supports seamless migration and roaming between radio access technologies that will coexist, (Idec Org,2020).

As defined by ITU-R (2015) (International Telecommunication Union), 5G is a system designed to meet the requirements of IMT-2020 established by the ITU-R M.2083 specification as shown in figure 1. These parameters are considered as requirements strategies for the development of 5G. Measurement requirements such as the Peak Data Rate with 20 Gbps Downlink and 10 Gbps Uplink experienced by users at a Downlink rate of 100 Mbps to 1Gbps and 50 Mbps Uplink. Better spectral efficiency compared to 4G (IMT-Advanced) technology. Furthermore, three times the Traffic Capacity is obtained per area of 10 Mbps/m2, with a Latency of 1 ms and Connection Density of 10 million devices/km2. Energy efficiency is better compared to 4G (IMT-Advanced) with 100 times the mobility reaching 500 Km/h proportional to data traffic. Figure 1 shows the main parameters of IMT-2022 (International Mobile Telecommunications), (ITU-R, 2015).

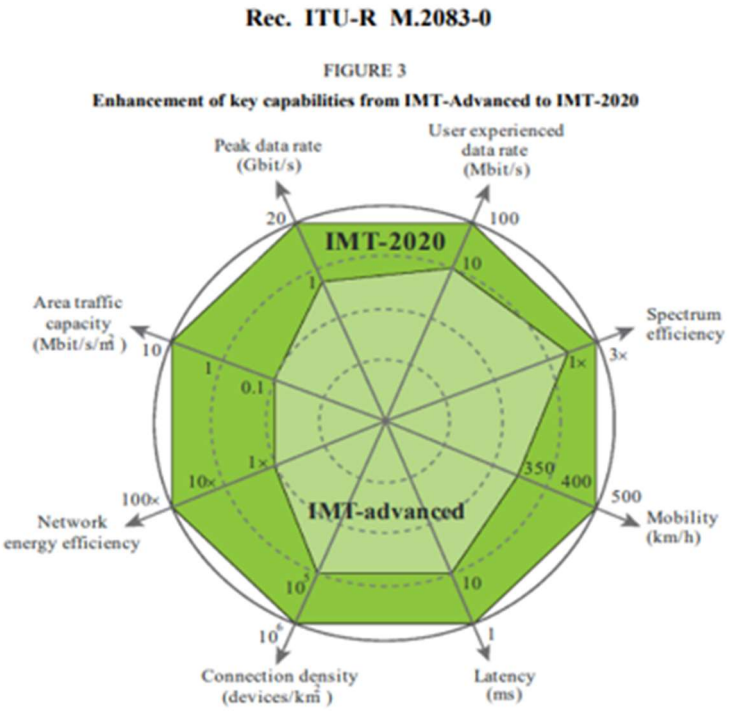


Fig.1. IUTR-R,2015

The adoption of 5G technology as a technological alternative to solve the growing demand for communication reflects an evolution of the telecommunications sector as a whole, and particularly a new advance in the use of mobile telephony. Within a scenario of technological convergence, which has placed a multitude of activities such as exchanging messages, watching videos, doing banking transactions, shopping and many others, 5G tends to multiply applications on cell phones and increase and intensify Internet-based connections of Things (IoT- Internet of Things), contributing to the development of industrial automation, among other areas (Idec.org 2020).

2. Literature Review

With the implementation of 5G mobile technology in Brazil, the scenario of countries that offer this technology to their citizens has expanded and become more competitive. However, those responsible for its implementation reinforce that 5G technology is not for the general public, but for the productive sector. The Minister of Communications of the Brazilian Government pointed out that 5G serves the industrial sector, in the same proportion that 4G serves people (Idec.org 2020).

The new 5G technology associated with industrial automation 4.0 will promote an increase in supply and a reduction in production costs in production companies, meeting the applied microeconomic calculations (Idec 2020).

The choice of production process depends on its efficiency. Efficiency can be evaluated from a technological point of view or from an economic point of view (VASCONCELLOS, M. Antonio 2015). Technical (or technological) efficiency: between two or more production processes, it is the process that allows the production of the same quantity of product, using less physical quantity of production factors; Economic efficiency: between two or more production processes, it is the process that allows the production of the same quantity of product, with a lower production cost.

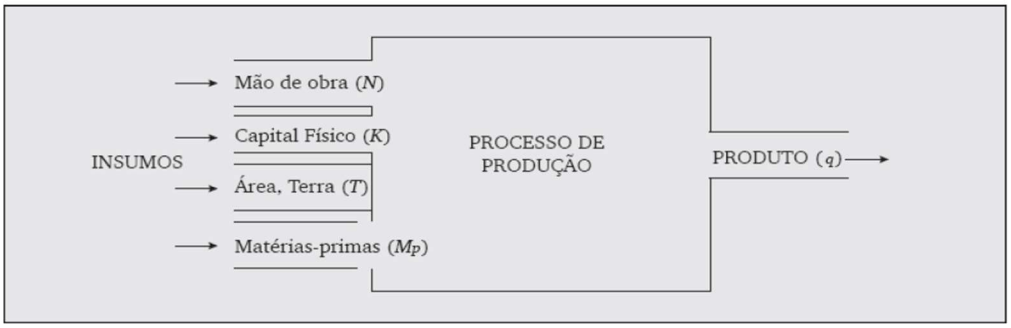


Fig. 2. The production process. VASCONCELLOS, M.Antonio 2015.

With the implementation of new Technologies (Intelligent Industry Concept), the cost of production / manufacturing drops, and its technical productive efficiency OEE (Overall Equipment Effectiveness) and Supply increase (VASCONCELLOS, M. Antonio 2015).

Supply: is the amount of a given good or service that producers and sellers are willing to sell in a given period. The general function of offering a good or service is determined by the following variables, where the variable (T) Technology contributes to the productive differential (VASCONCELLOS, M. Antonio 2015).

Formula: $= f(pi, \pi m, pn, T, A)$

q_i^s = quantity supplied of good i/t
pi = price of good i/t
πm = price of factors and production inputs m (labor, raw materials, etc.)
pn = price of n other goods, substitutes in production
T = technology
A = climatic and/or environmental factors

Labor productivity (volume of production per unit of work) can increase if there are technological advances, even if a certain production process presents decreasing returns for the labor input. As we move from point A, on the O1 curve, to B, on the O2 curve, and to C, on the O3 curve, over time, labor productivity increases as shown in Figure 3 (PINDICK, Robert; RUBINFELD 2013).

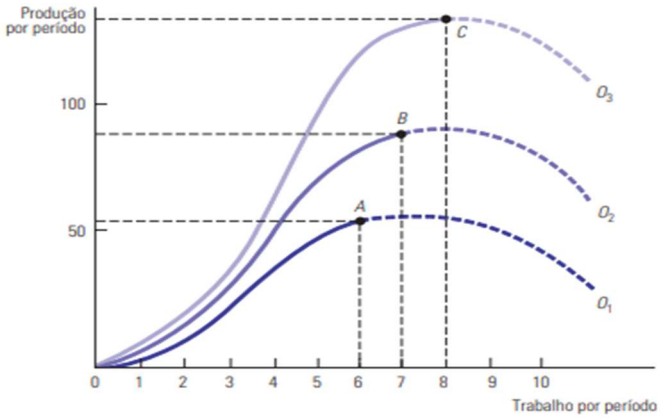


Fig. 3. Production versus Work. PINDICK, Robert; RUBINFELD 2013

Companies in the industrial/manufacturing sector are investing in technology every day to increase their production efficiency, reduce their production/manufacturing costs, improve the quality of their products and remain competitive in the market. Variation in supply (figure 4) displacement of the supply curve, due to changes in the price of other goods (substitutes in production), in the cost of production factors or in business objectives (PINDICK, Robert; RUBINFELD 2013).

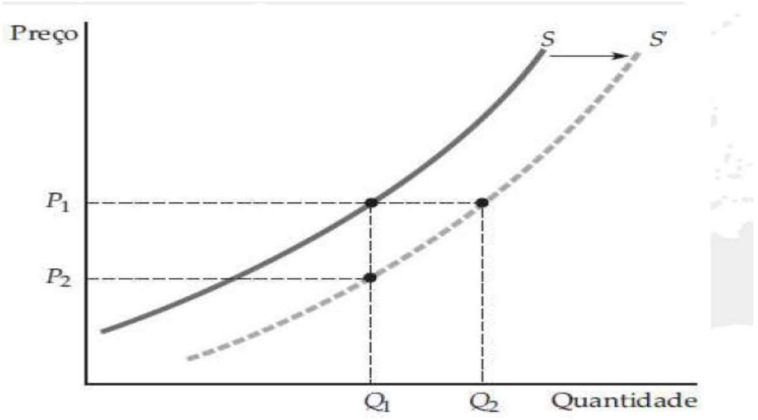


Fig. 4. Supply curve. PINDICK, Robert; RUBINFELD 2013

In minimizing costs with variation in production levels, The expansion path illustrates the combinations of Capital (K) and Labor (L) that present the lowest cost for each production level.
Isoquant – Curve that shows all combinations of inputs that result in a certain level of production (PINDICK, Robert; RUBINFELD 2013).

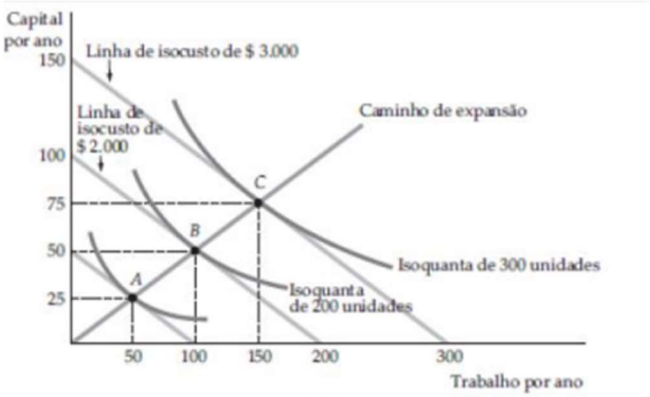


Fig.5. producers, consumers and competitive markets. PINDICK, Robert; RUBINFELD 2013

The application of a research mental map, together with the company's management, is necessary in order to demonstrate the ideas that need to be synchronized for the implementation of automation, in order to achieve the objectives of technological evolution in production.

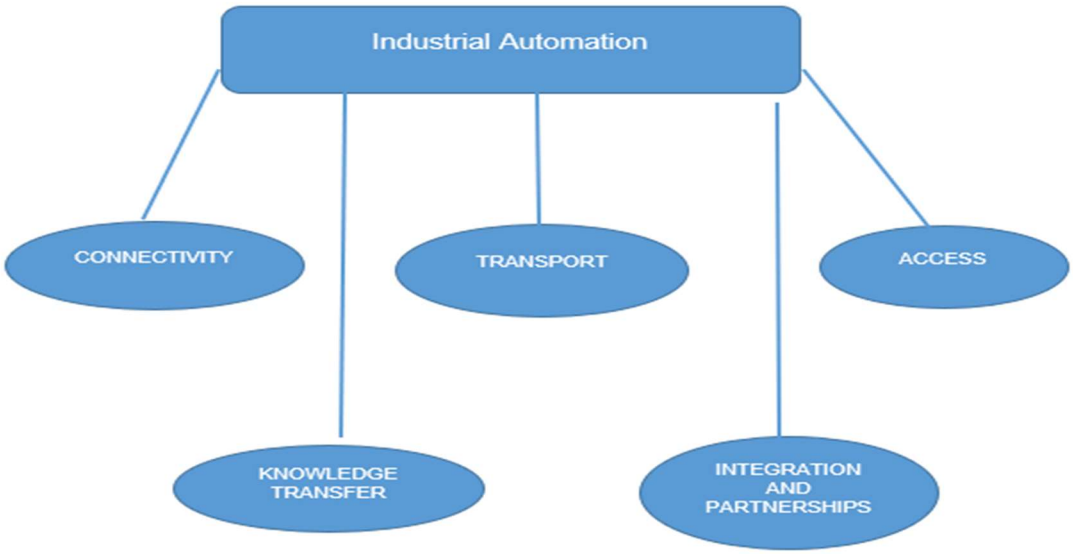


Fig.6. Author

Connectivity. All devices in a company with management for decision making

Transport. Enabling the transport of logical information with the cybersecurity of 5g connectivity.

Access. Enable secure access for everyone involved to the industry 4.0 system

Knowledge transfer. Develop capabilities Needed

Integration and partnerships. Define and develop capabilities.

In order to support the strategic planning, the company/industry must carry out, in this first stage, the self-assessment research of the processes, analyzing its level of maturity and the objective it wants to achieve. For this purpose, it is recommended to use an organizational, economic and technological maturity

assessment model. In this way, resources are directed towards a quantitative and qualitative assessment of the level of complexity of the technology used, people management, investments, tangible and intangible assets, and maintenance policies, for the implementation of the company's digital transformation (Enegep , 2017).
As a premise for analyzing the company's maturity, internal surveys were carried out with employees and managers, in order to clarify the items necessary for the implementation of Automation, considering qualities Figure.7, for quantities of functions of company.

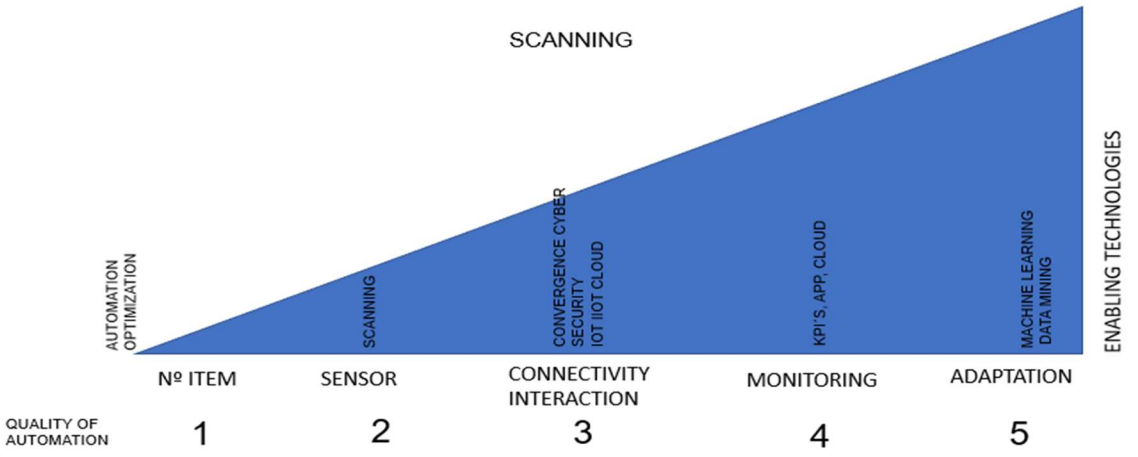


Fig.7 Author

3. Methodological Proposal

In neoclassical microeconomics, technology is defined as a set of all possible production methods — that is, combinations of capital and labor — that allow for the production of different quantities of a good without changing the proportion of inputs. Each production method represents some technically efficient way of combining inputs in some given proportion so as to bring about the required output. The choice of the economically efficient method depends on the relative price of the factors employed and the quantity to be produced. The production function is the main analytical instrument of microeconomics that represents technology. It is a mathematical relationship between the quantity produced of a good and the quantity of inputs needed for this (TIGRE, Paulo Bastos 2006).

All production methods that correspond to the state of the art and scientific advances are included in the same production function. Technological evolutions in production processes represent a displacement of the production function, allowing an increase in the quantity produced of a good without changing the quantity of inputs used. The different forms of combinations of inputs (capital and labor) to produce a given quantity of a good are geometrically represented by the isoquant. Figure 8 shows that, in the situation of isoquant X2, the same quantity of goods can be produced as in X1, due to technological change. In the new efficient combination (X2) it will use less number of factors to produce the same good, resulting in lower unit production costs. Technical progress is shown by a line that optimizes the use of production factors at the intersection with isoquants representing different technologies. The isoquant shows the marginal rate of technical substitution between productive factors, indicating the amount that can be saved from a production factor by increasing the use of the other factor by one unit, with the quantity produced remaining fixed (TIGRE, Paulo Bastos 2006).

We know that technological change in processes can save work (through automation), save materials or energy (via more efficient processes) or, eventually, capital. Simplifying assumptions adopted by the production function consider technological change as neutral, that is, the displacement of the production isoquant does not change the slope of the curves. Therefore, the X1 and X2 isoquants are parallel and the line representing the technical change always has a 45° slope. This means that the marginal product of both factors increases by the same amount. The production function represents only the technological process changes. Product innovations are considered as exploration of new markets, since the market concept is restricted to perfectly homogeneous goods. New products aim to replace existing products meeting the

same type of need. The new market is a temporary monopoly, the duration of which depends on the speed of imitation by the competition and, in some cases, on legal protection through patents. Microeconomics has always been concerned with analyzing firm behavior in different market structures, bearing in mind the issue of price formation. This concern led her to focus the discussion on technological change on the relationship between innovation and market structure (TIGRE, Paulo Bastos 2006).

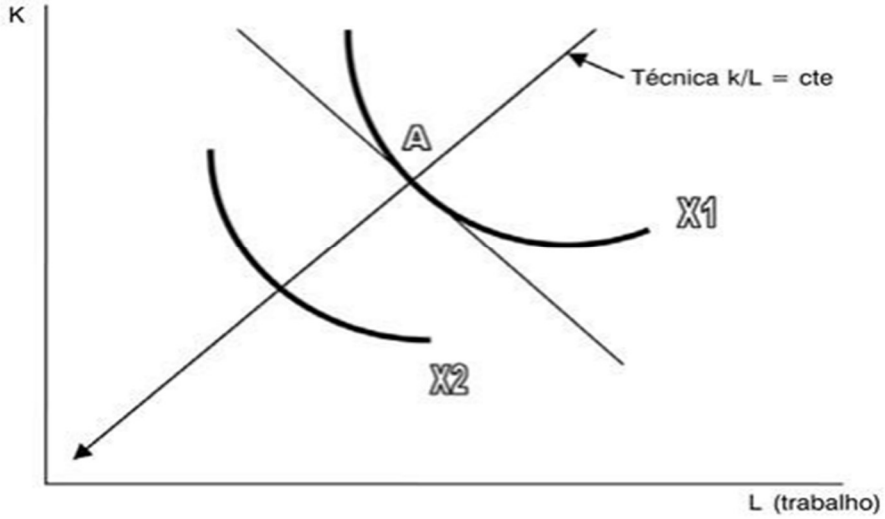


Fig.8. Isoquant X2, the same quantity of goods can be produced as in X1.
TIGRE Paulo Bastos 2006

3.1 Factors determining the quantity offered of a good or service. (Pharmaceutical industry).

The quantity supplied of a good or service is also affected by extra-price factors, a set (price and extra-price) of factors that determine the quantity supplied of a good or service: • Price of the good (Pb) □ changes the quantity supplied. • Price of production factors (Pf). • Price of substitute goods in production (Ps). • Technology (T). Supply function: Qo = f (Pb, Pf, Ps, T). (Microeconomia Ministry of Health, Executive Secretariat 2021).

Technology: Qo = f(T) (Example)

A pharmaceutical laboratory acquired a new type of machinery – a capital asset – designed to speed up the production of the drug Alfa. It is known that the previous machinery, operated by a single worker, produced the amount of 100 pills/hour. The introduction of the new machinery increased the production of a single worker to 150 pills/hour. The new machinery 41 MINISTRY OF HEALTH therefore led to an increase in production via increased productivity. In other words, the use of a new technology in the production process increased production by 50 units/hour, with the additional units representing an improvement in the product-per-worker/hour ratio, which we call increased productivity. There is, therefore, a direct relationship between technological improvements and the quantity offered of a given good or service (Microeconomia Ministry of Health, Executive Secretariat 2021).

3.2 Analyzes based on the Strategic Planning and Maturity of the companies.

The Brazilian state bureaucracy delays not only the investment of 180 billion reais in telecommunications infrastructure, but also delays billions of investments in the productive sector and leaves us at a disadvantage in relation to other countries that are already implementing and restructuring their park industrial for industry 4.0. In addition to the technological issue, another obstacle to the development of industry 4.0 in Brazil is the lack of own resources and adequate funding for it, according

to the national industry confederation (CNI). “The main industrialized nations have placed the development of Industry 4.0 at the center of industrial policy strategies to preserve and increase their competitiveness, that is, the strategic planning of companies is essential to map the development of Industry 4.0. The development of new production technologies led many productive sectors to change paradigms. Since the First Industrial Revolution, the way of working and the dynamics of the economy and market have been changing. Figure 6 shows the evolution and current phase of the industrial revolution we are in (Aprepro 2019).

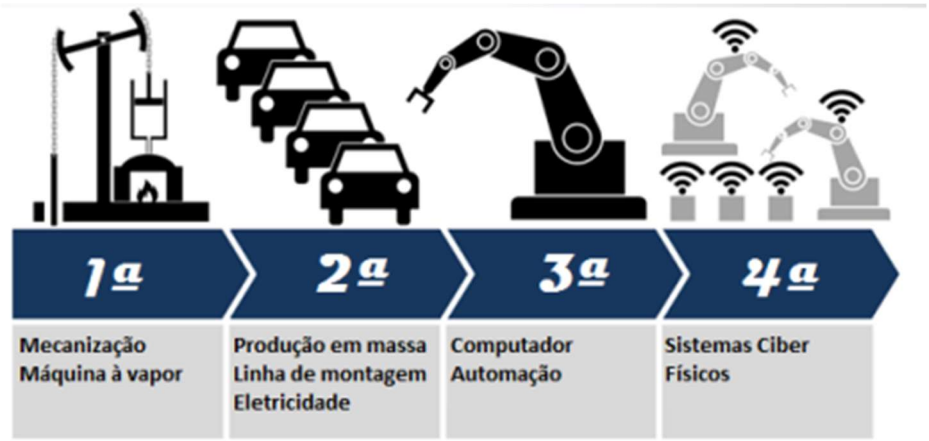


Fig. 9. Industrial Revolution 1,2,3 and 4.0. Aprepro IX Brazilian Congress of Production Engineering 2019

Based on the strategic planning, the company/industry must carry out a self-assessment of processes in this first stage, analyzing its level of maturity and the objective it wishes to achieve. For this purpose, it is recommended to use an organizational, economic and technological maturity assessment model. In this way, resources are directed towards a quantitative and qualitative assessment of the level of complexity of the technology used, people management, investments, tangible and intangible assets, and maintenance policies, for the implementation of the company's digital transformation (Enegep , 2017).

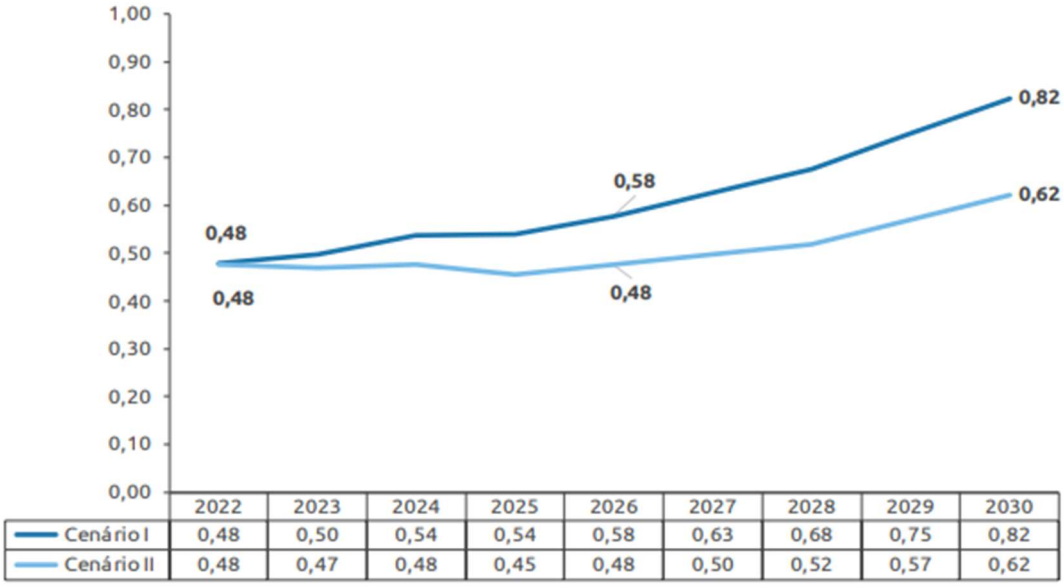
4. Expected Results

Let's say that in the short term, the digital transformation is expected to boost productivity on a large scale with 5G, faster and with greater data transmission capacity. A study carried out by Nokia, a Finnish telecommunications and technology company, and the consultancy and research firm Omdia reveals that the expected impact of the fifth generation (5G) in the country is US$ 1.2 trillion in the period from 2021 to 2035 (This Is Money, 2022**).**

This amount of money is capable of adding one percentage point per year to the Brazilian GDP, becoming one of the engines of the economy in the coming years and the lever for resuming post-pandemic growth (This Is Money, 2022).

The projection of potential GDP growth is the result of growth in the working-age population (PIA) and labor productivity; the adoption of 5G will only impact the last indicator; and the technology will be commercially available from 2022. Thus, two scenarios were simulated: in the most optimistic (I), 5G coverage 1 grows rapidly between 2022 and 2030, reaching 0.82% in the last year; in the alternative scenario (II), coverage reaches 0.62% at the end of the period, as shown in Graph 1 (CNI 2021).

Annual growth projection of potential Brazilian GDP per capita in scenarios with fast (Scenario I) and slow (Scenario II) adoption of 5G in % The simulation indicates that the speed of dissemination of 5G connections and their proportion of total mobile accesses would have a significant impact for the economy in the short term (see Fig.10).



	2022	2023	2024	2025	2026	2027	2028	2029	2030
Cenário I	0,48	0,50	0,54	0,54	0,58	0,63	0,68	0,75	0,82
Cenário II	0,48	0,47	0,48	0,45	0,48	0,50	0,52	0,57	0,62

Fig.10. Potential GDP. CNI 2021 National Confederation of Industry based on IBGE, IPEA and World Bank data.

5. Final Considerations

We understand that in government policy, it must be made evident to all sectors of the economy that 5G is a fundamental infrastructure of society, a platform that, by providing ubiquitous and ultra-fast broadband, will boost the competitiveness of the national economy and the capacity to develop industries and technologies. Policymakers must encourage and provide incentives for 5G investments as soon as possible.

Bureaucracy is unquestionably an obstacle to the rapid spread of 5G in Brazil, the excess of municipal laws, the tax burden and infrastructure obstacles are impeding factors for the employment of millions of dollars in the Brazilian economy. 5G technology is one of the examples that presents everything that has been happening for years in our country, economic stagnation, lack of job creation and competitiveness of Brazil in relation to other countries due to the large participation of the state in the market (Source:author).

To become a developed country, the first step is to deregulate, reduce bureaucracy, create a favorable environment for business, have operational efficiency, agility and functionality. There is no developed nation without efficiency. With all of the above, it is clear that even with the delay we have compared to developed countries, 5G will bring investments and a huge digital transformation in all regions of our home. Let us hope that in the future we will have a minimal state, which will allow the market to function and become competitive with the world (Source:author).

6. Bibliographical References

1. APREPRO. Paraná Association of Production Engineering, available at https://aprepro.org.br/conbrepro/2019/anais/arquivos/10192019_121035_5dab32ab50f71.pdf last accessed Jan 02, 2023.
2. CNI. National Confederation of Industry. 2021. (Doc PDF) available at https://www.portaldaindustria.com.br/publicacoes/2021/12/tecnologia-5g-impactos-economicos-e-barreiras-difusao-no-brasil/ . Last accessed on October 20, 2022.

3. ENEGEP. 2017. Available at: https://www.academia.edu/59174889/Etapas_para_implanta%C3%A7%C3%A3o_da_Ind%C3%BAstria_4_0_ Accessed on: Dec. 22, 2022
4. IDEC. 5G TECHNOLOGY AND INTERNET ACCESS IN BRAZIL. 2020. available at https://idec.org.br/pesquisas-acesso-internet Last accessed on October 20, 2022.
5. THIS IS MONEY. 2022. available at https://www.istoedinheiro.com.br/o-impacto-trilionario-do-5g/ Last access on January 02, 2023
6. MICROECONOMICS [electronic resource] / Ministry of Health, Executive Secretariat, Department of Health Economics, Investments and Development. – Brasília : Ministry of Health. 2021. Available at https://bvsms.saude.gov.br/bvs/publicacoes/cadernos_economia_saude_microeconomia_1ed.pdf Last accessed on January 2, 2023.
7. PINDICK, Robert; RUBINFELD, Daniel. Microeconomics. Pearson, Sao Paulo, vol. 8, p. 201, 2013.
8. TIGRE, Paulo Bastos, 1952- Innovation management: the technology economy in Brazil / Paulo Bastos Tigre. – Rio de Janeiro: Elsevier, 2006. – 7th reprint. il.
9. VASCONCELOS, M. Antonio Sandoval de Economics: micro and macro: theory and exercises, glossary with the 300 main economic concepts / Marco Antonio Sandoval de Vasconcellos. – 6. ed. – São Paulo: Atlas, 2015. ISBN 978-85-97-00202.