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TECHNOLOGICAL UNEMPLOYMENT: AN APPROXIMATION TO THE LATIN AMERICAN CASE

DESEMPLEO TECNOLÓGICO: UNA APROXIMACIÓN AL CASO LATINOAMERICANO

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ABSTRACT

Recent advancements in Artificial Intelligence (AI), robotics, control systems, software and related technologies have revived the debate on the influence that technology has on labor markets. So far, the focus of the literature has been on advanced economies. This document aims to analyze the following variables: domestic spending in science and technology, GDP per capita, nominal minimum wage, domestic spending in education and their impact on unemployment rate in seven Latin American countries from 1996 to 2011. Panel data was used to measure the relation of these variables with unemployment rates in the region. The results allowed us to conclude that investment in Science and Technology in the region has not reached levels that potentially reduce employment; on the contrary, innovation is regarded as a source of labor productivity gains. The broader implications of technology and automation are yet to be seen, however, both firms and the public sector in the region must prepare for massive technological unemployement, as predicted by recent models.

KEY WORDS

Technological innovation; unemployment; science and technology investments, gross domestic product.

RESUMEN

Avances recientes en Inteligencia Artificial (IA), robótica, sistemas de control, software y tecnologías relacionadas han revivido el debate sobre la influencia que la tecnología ejerce en el mercado laboral. Hasta el momento, el enfoque de la literatura se ha dado en economías avanzadas. Este documento busca describir y comparar las siguientes variables: gasto doméstico en ciencia y tecnología, PIB per cápita, salario mínimo nominal, gasto doméstico en educación en siete economías latinoamericanas y su impacto en la tasa de desempleo durante el periodo 1996 a 2011. Se usaron datos panel para medir la relación de las variables con las tasas de desempleo en la región. Los resultados nos permitieron concluir que la inversión en ciencia y tecnología en la región no ha alcanzado niveles que reduzcan potencial-mente el empleo; por el contrario, la innovación es vista como una fuente de ganancias en productividad en la mano de obra. Las implicaciones más amplias de la tecnología y la automatización todavía no son evidentes, sin embargo, tanto las firmas como el sector público en la región deben prepararse para el desempleo tecnológico masivo que se ha estimado en modelos recientes.

PALABRAS CLAVE

Innovación tecnológica; desempleo; inversión en ciencia y tecnología, producto interno bruto.

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INTRODUCTION

The influence of technology and innovation on labor markets has been a recurring theme of study for economists and social scientists since the Luddite movement in England that opposed the integration of the spinning jenny in yarn production in the 19th century. (Autor, 2015) However, most of the specialized literature has focused its attention on advanced economies, leaving emerging markets out of their scope of analysis.

In this paper, we address the following question: what could be the relationship between domestic expenditure in Science and Technology (S&T) and education and the unemployment rate in seven Latin American economies? To shed light on this issue, we analyzed panel data from Argentina, Brazil, Colombia, Costa Rica, Mexico, Panama and Uruguay for the period 1996-2011. More specifically, the document aims to review the most recent and relevant research on the topic of technological unemployment, reviewing it in a Latin American context. Finally, it will briefly describe the public policy options encountered in the literature and their implications for the private sector.

Keynes (1930) in the short essay *Economic Possibilities for our Grandchildren,* mentioned how the increases in efficiency in the different production processes would result in the replacement of labor by capital, thus creating technological unemployment. Handel (2003) who based his conclusions primarily on the works by (Woirol, 1996; Bix, 2000) provided a glance of the literature on the subject matter during the 20th century, focusing on the public policy response from different U.S. administrations.

Autor (2015) described the associated forces that have shaped labor markets throughout most of the 20th and beginning of the 21st century in developed countries. Those forces include changes in the relative supply of college and non-college labor, rising trade penetration, offshoring, globalization of production chains, declines in labor union penetration, and the changing (declining) share of labor in GDP. However, the one force that was singled out in the literature is the impact of information technology (IT).

This focus on information technology has supported the hypothesis of Skill Biased Technological Change (SBTC) discussed by (Bell, 1996; Autor, Katz & Kruger, 1998; Bresnahan, Brynjolfsson & Hitt, 2002; Autor, Levy & Murnane, 2001). The SBTC hypothesis argues that the introduction of computers and information technologies reduced the demand for less-skilled workers hence reducing the employment options for this population but increasing the demand for medium and high skilled workers.

Goos and Manning (2003) contributed to the discussion showing evidence of a market polarization in the United Kingdom where middle-skilled jobs are being lost due to the implementation of technologies. Additional studies (Beaudry, Green & Sand, 2016; Jaimovich & Siu, 2014) pointed out that technology not only affects those with lower skills but also those occupations with higher cognitive tasks.

In a seminal work by Frey & Osborne (2013), the authors introduced a novel approach by quantifying the probability of job categories prone to automation in the United States. The result showed 47% of the jobs in the United States are in the high-risk category for computerization/automation in the coming 10-20 years. In the case of Germany, Bonin, Gregory & Zierahn, (2015) replicated the method suggested by Frey & Osborne and found comparable results with 42% of jobs with a probability over 0.7 for automation in coming years. Monroy, Moreno & Santos (2015), suggested the lack of reliable and comparable data in emerging countries to classify occupations as seen in the United States and Germany.

Due to data availability limitations, the lack of a uniform and comparable job classification code among sample countries (e.g. the International Standard Classification of Occupations (ISCO) ISCO-88, ISCO-08) makes it impossible to replicate the methodology proposed by Frey and Osborne at this stage.

TECHNOLOGY, INNOVATION AND UNEMPLOYMENT

Contemporary society is currently reaping the benefits of decades of investment and cumulative innovation in information technology and telecommunications. The exponential growth of computing power (Moore's Law), artificial intelligence, cloud computing, machine learning, robotics, 3D printing, big data and the Internet of things (IoT) are transforming most of human experience. These technologies are creating and making accessible new products and services for massive consumption in an unprecedented pace, but also threatening jobs in occupations of all skill categories. (Manyika et al., 2013; Ford, 2015; Pratt, 2015; Rifkin, 2015; Sachs, 2015)

Handel's (2003) characterization of information technology provided a quick glimpse of the scope and reach of IT. "IT systems are frequently fast, precise, high storage, high capacity, highly flexible, reprogrammable, and automatic or self-acting. They may be able to record, process, communicate, and react to information from users and feedback from the environment in more or less sophisticated ways." (p. 12)

Brynjolfsson and McAfee (2014) argued that modern society has reached a second machine age. The first age automated muscular work freeing labor from the agricultural sector, leading to the manufacturing and service sectors that employ the bulk of the population. The second machine age would automate complex work and tasks, which until recently, was the exclusive domain of humans.

Vivarelli (2012) presented the six compensation mechanisms found in the literature regarding the labor savings that lead to the implementation of technological innovations:

- Job creation in the capital goods sector: innovations that displace workers from a certain sector would create new jobs associated with these innovations.
- Reduced prices: given the increased productivity resulting from the implemen-tation of innovations, it is estimated that the unit production costs decreases.
- New investments: the gap between falling production costs and falling prices would generate surpluses that can be invested in new production and new jobs.

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- Salary adjustments: the implementation of technologies and innovations that reduce labor would reassess the price of labor, thus, it could enable firms to absorb more labor at a lower price.
- Income: savings achieved due lower production costs could be translated into higher income pushing up demand.
- Creation and commercialization of new products: the creation of new sectors and industries would employ available labor freed due to technological change.

In this regard, the effects of technological change on the labor market are both quantitative (unemployment) and qualitative (demand for more skilled labor to operate optimally implemented technologies); hence the hypothesis of Skill Biased Technological Change (SBTC), according to which the limitation of technology implementation is due to the shortage of skilled labor to operate innovations.

Autor, Levy and Murnane (2001) studied the effects the use of computers introduced in the labor market had in the United States between 1970 and 1998, particularly highlighting an increase in the demand for labor with a tertiary education starting in the 1980s. They emphasized the difference between certain easy to automate tasks (routine and programmable) versus tasks considered difficult to automate like driving an automobile or a truck. However, recent innovations have demonstrated that the world is on the verge of autonomous vehicles with minimal or no human intervention to operate. (Bertoncello & Wee, 2015)

Autor (2014) highlights the polarization of the labor market, as evidenced by the simultaneous growth of highly skilled, well-paid jobs with the growth of low-skilled and low-paid ones. Considering the SBTC hypothesis and some data collected by Manpower (2013), there are labor shortages in highly skilled jobs associated with the lack of training in these specific skills. Ironically, the report identified both unemployment and labor shortages. Formal education and training programs are particularly slow to adapt to the rapid technological changes; young people are graduating from universities with degrees in danger of obsolescence and the opportunity cost is losing a new generation of workers with the necessary skills to cope with a highly automated future. A profound discussion on the subject matter is found in Tether *et al.* (2005).

The academic study of the effects of technology on labor markets in Latin America is incipient. Crespi and Tacsir (2012) approached the issue by comparing data from innovation surveys and its impact on employment: their observations found no "displacement effect" due to the introduction of product innovations. On a further note, they described the relationship between innovation and employment in the region as "idiosyncratic," not to mention differences in economic and societal structure, thus, making it difficult to infer similar insights from developed countries.

METHODOLOGY DESCRIPTION

Data Set

An empirical analysis of the variables was performed using panel data from Argentina, Brazil, Colombia, Costa Rica, Mexico, Panama and Uruguay for the period 1996-2011. . These countries were selected based on the criteria of highest investment in science and technology (S&T) as share of their GDP.

In addition, two sets of countries were created using GDP per capita as a measure for differentiation in order to separate the effect their particular national economic structure may have within the model. Figure 1 shows Argentina, Brazil, Mexico and Uruguay maintaining an average GDP per capita of $9,000 (in constant USD), evidencing higher growth rates than the cases of Colombia, Costa Rica and Panama where GDP per capita averaged approximately $6,000 USD (in constant USD) during the observed period. Given the difference between the two groups, the analysis was done separately.

Figure 1. GDP per capita, 1996-2011.
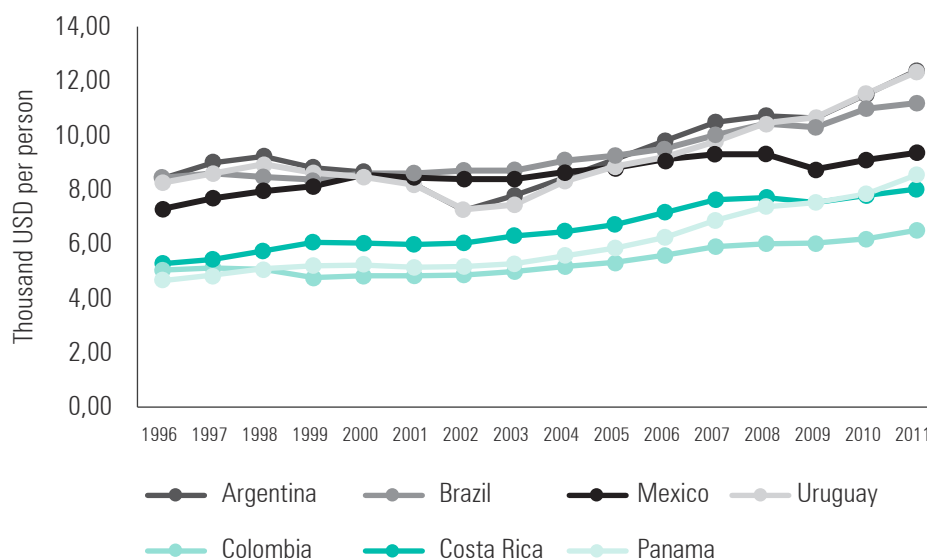
Source: Calculations by the authors based on the ECLAC data (2015).

Explanatory variables for Unemployment

Due to data availability as Monroy et al (2015) mentioned in their publication, the approach conducted here aimed to analyze if there was a relationship between innovation (measured by spending on science and technology) and unemployment; in other words, if national investments in S&T could create technological unemployment in the selected countries. Furthermore, in order to give greater significance to the model, other economic and social variables were included as shown in Table 1[3].

Table 1. Independent variables in the Model.

	VARIABLE	UNIT OF MEASURE	DATA SOURCE
S&T	Domestic expenditure in Science and Technology	Percent of GDP	UNESCO database and statistical publications
GDPpc	Gross Domestic Product per capita	USD constant (1984=100)	ECLAC database and statistical publications
SAL	Nominal minimum wage deflated by the CPI of each country	Average annual rate (2000=100)	ECLAC database and statistical publications
EDU	Public Expenditure on Education	Percent of GDP	IDB Publications

Source: Authors summary.

As previously stated, the relationship between innovation (measured as spending on science and technology) could have two effects on the unemployment rate: either it increases it due to the automation of tasks previously performed by humans, or it decreases it because of growth in production levels that may require additional skilled labor and non-automated processes.

With regard to the GDP per capita (GDPpc), it is believed that an increase in production would foster business activity and industrial growth, thus stimulating job creation, hence the inverse relationship between GDPpc and unemployment. Wage levels were also considered as inversely related to unemployment assuming that higher salaries would attract more talent to the work force. As for the last variable, the effects of educational attainment on labor markets and productivity have been widely researched, this is why education is considered to be inversely related to unemployment (Becker, 1962; Mincer, 1991; Autor & Handel, 2009).

3 The data include 112 observations from the study of 16 periods for 7 groups, which complete panel data of 448 observations. In order to work with stationary variables, logarithms are applied to the independent variables to reduce the tendency of the data towards dispersion. Thus, allowing to estimate a reliable and effective model (Gujarati, 2004). Additionally, a subsequent differentiation is made: each of real variables in the model underwent the augmented Dickey-Fuller test (ADF).

The dependent variable

The regression analysis proposed is set based on the characteristics of the dependent variable. The unemployment rate is restricted between values of 0 and 1, so that its growth will be mitigated when reaching its maximum value, as will its decline when reaching its minimum value.

Thus, unemployment by means of automation – Technological Unemployment (TU) – is represented by a sigmoidal growth ("S" Form - See Figure 1) which is curbed as it reaches its peak, given it is calculated within a finite limit ($0 \leq TU \leq 1$).

Even though it may have an exponential growth at one stage of its evolution, it does not reach infinite rates but it is stabilized in the long term, either by implementing public policies that control it or by the natural limit of the population.

Figure 2. "S" Form Shape of Technological Unemployment.
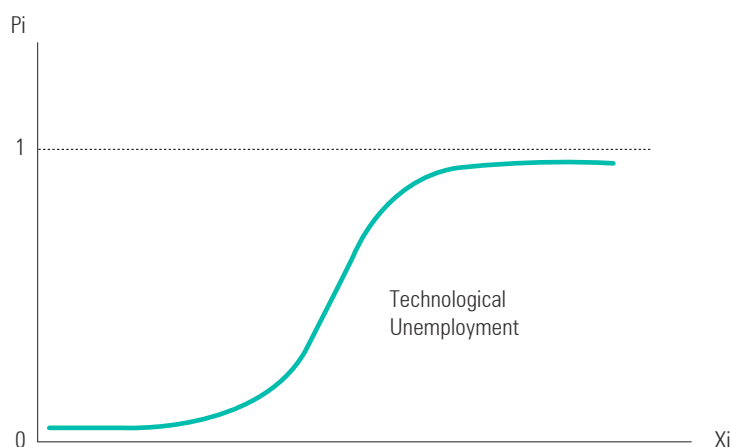
Source: Authors.

Given this specification, consistent estimations of ß can be obtained by maximizing the logarithm of the likelihood function

$$X_{it}\beta)] + (1 - Y_{it})\log[1 - f(X_{it}\beta)]\} \tag{1}$$

The distribution of probability will come given by a probit model, which function of distribution originates by the integral:

$$P_{it} = E(Y_{it} = 1|X_{it}) = f(X_{it}\beta) = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{X_{it}\beta} e^{-\mu^2/2}d\mu \tag{2}$$

Where the probability of success, P_{it}, were defined by the area under the $X_{it}\beta$ curve. In addition, random effects were assumed:

$$P_{it} = E(Y_{it} = 1|X_{it}, \mu_i) = f(X_{it}\beta + \mu_i) \tag{3}$$

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Since there is assumed that it exists strict exogenous influence from X_{it} subject to μ_i, and that the Y_{it} are independent in time given X_{it} and μ_i (Gujarati, 2004)[4].

Considering this, in order to have a statistically significant model, Y turns into a binary variable where: Y = 1 if the event is successful or Y = 0 for the opposite case. In this sense, the unemployment variable was transformed to "1" in those values in which the unemployment rate increased above the country average and "0" when the unemployment rate was below the country average for the years studied.

TECHNOLOGICAL UNEMPLOYMENT IN LATIN AMERICA

Unemployment and Innovation in Latin America

According to Inter-American Development Bank, IDB, (2010), the countries of Latin America must maintain policies that improve the quality of life of their populations, attending to priorities such as education, health, poverty, among others; nevertheless, it also affirms that the challenges of modern society force the countries to face the technological changes that affect their economies. On a separate note, Crespi and Tacsir (2012) argued that the productive structure of the region, dominated by commodity production, preponderance of Small and Medium Enterprises (SMEs) and low technological intensity of manufactured goods could generate different results in the mix of innovation and employment.

Rodrik (2015) singled out Latin America as one of the regions most vulnerable to "premature deindustrialization" suggesting that globalization, trade and labor-saving technologies have hindered the development of a strong manufacturing base (and jobs) in the area. Additionally, the author commented on the political and economic backlash of this phenomenon, including political instability and democratic failure.

In the literature, it was found that the region had made changes regarding the levels of expenditure dedicated to Science and Technology. According to the IDB (2010), Latin America showed substantial advances in some indicators of recorded patents and increased output of scientific publications. However, the progress was focused in only a few countries, therefore, the region continued to lag behind in regard to science and the technology investment and achievements compared to the rest of the world. Figure 3 shows some of the gaps in the levels of expenditure in S&T between different countries of the region.

Brazil stands out as the country that invested the most in S&T as a share of GDP compared to its neighbors: it even doubles the regional average. On the other hand, countries like Colombia were behind regional peers and below average.[5]

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4 In the regressions, Hausman tests are realized to confirm the presence of random effects, reason by which the estimations are elaborated under the assumptions of a Probit model of binary regression.
5 In the countries that are not included, the average of the expense in Science and Technology is below 0.1 as percentage of the GDP.

Figure 3. Average Science and Technology expenditure as percentage of the GDP, 1996-2011.
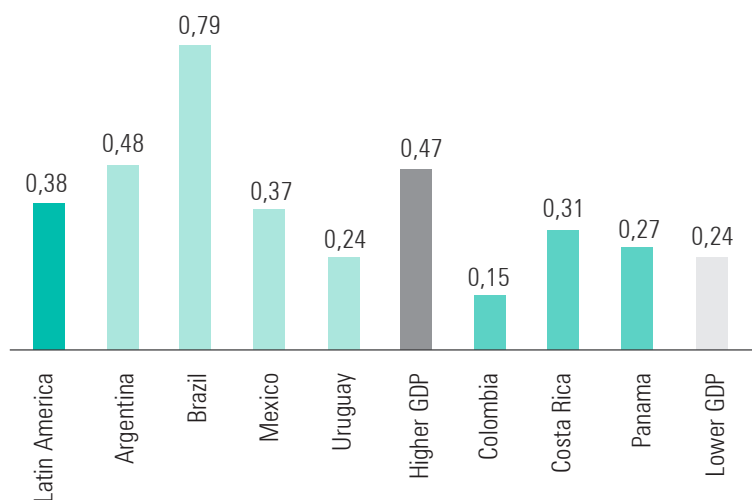
Source:Calculations by the authors based on the ECLAC data (2015).

In Figure 4, we can see the increasing trend of the expense in S&T by the countries of the sample. The investment in this segment rose (on average) from 0.26% of the GDP in 1996 to 0.51 % in 2011; in the year 2009 it reached a peak at 0.53%, being the countries with high GDPpc those that invested the most in this category. The principal characteristic of the indicator is its volatility during the period of study, which demonstrates high rates of growth particularly in the year 2000 and 2006.

Figure 4. Evolution of the Unemployment and the Expense in Science and Technology in Latin America.

Source: Calculations by the authors based on the ECLAC data (2015).

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Regarding the unemployment rate, the regional trend was downwards from 2002 and the volatility of this indicator was minimal. Between 1996 and 2000 the data showed an increase in the unemployment levels, due to real exchange rate appreciation as argued by Ros (2005); after 2002 the fall in unemployment is supported by some hypotheses associated with the commodities boom experienced by some regional countries during most of the first decade of the 21st century (World Bank, 2015).

Vivarelli (2012) suggested that one of the compensation mechanisms of automation is the readjustment in wages, taking into account the implementation of innovations that reduce the need to use workforce - an adjustment was assumed in the price of work. When comparing the behavior of wages and the level of expenditure in S&T, see Figure 5, a relative stagnation was observed in the wages of the region in spite of the increase in the S&T investment. This stagnation trend in wages was documented in advanced economies, as the average productivity increased the return of the workforce, (labor share) has declined (Karabarbounis & Neiman, 2013; Autor, 2014).

Figure 5. Evolution of the minimum wage and the expense in Science
and Technology in Latin America.
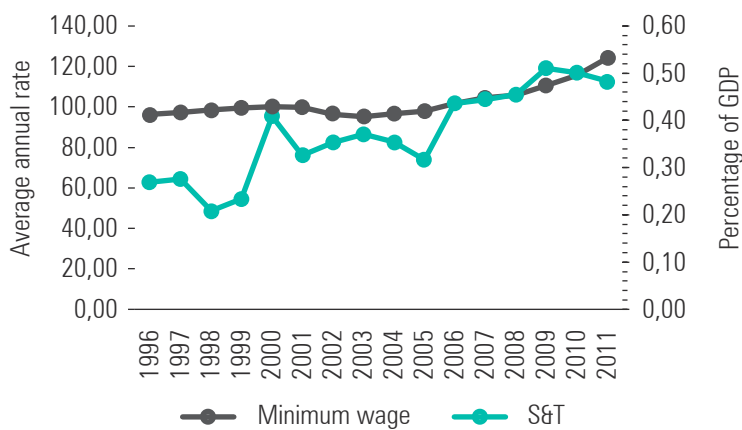
Source: Calculations by the authors based on the ECLAC data (2015).

The IDB (2010) argued the existence of a synergy in which investments in innovation, productivity and per capita income were mutually reinforced and allowed the countries to achieve growth rates sustained over time. Therefore, the stagnation of wages experienced in regional economies was perceived as a barrier to promote growth and technological development.

Relation between Unemployment and Science and Technology Expenditure

The econometric estimations were calculated to assess the correlation between Science and Technology expenditure as share of GDP, GDPpc, median wages and the expenditure in education on the unemployment rate.

Table 2 summarizes the results: the estimations (1), (3) and (5), include the regression with four independent variables proposed in this research, whereas the estimations (2), (4) and (6) showed only the statistically significant regressions of the models.

Table 2. Regressions results.

Xi	LATIN AMERICA		HIGH GDP pc		LOW GDP pc	
	ESTIM1	ESTIM2	ESTIM3	ESTIM4	ESTIM5	ESTIM6
S&T	-0,91294	-----	-3,33307	-0,572018*	-2,70269	
GDP	-12,4134*	-10,4628***	-9,04758	-9,123885*	-35,7863*	-22,1295 ***
WAGE	-3,21707*	-2,44061**	-2,18916	-2,504494*	1,28156	-----
EDU	-2,24173	-----	3,17231	-----	-1,51878	-----

Note: (*) 10% significance. (**) 5% significance (***) 1% significance.
Source: Summary of the results. Calculations by the authors.

The first regressions of every group proved not to be significant to explain the unemployment rate during the period 1996-2011. Nevertheless, after some transformations in the line of regression it was found that results provided some explanation hypotheses about the variations of the unemployment in the region.

The Latin American case

According to the statistical results, there was no evidence that expenditures in Science and Technology were related to the unemployment rate in the region; contrasting what was found in specialized literature on advanced economies, technological innovation in the observed period did not generate unemployment in Latin America.

The model showed that unemployment rates were only explained by the GDP and the wages, a 1% increase in the GDPpc increased the probability of reducing the unemployment by 10%, whereas a 1% increase in the salary raised the probability of reducing the unemployment by 2.4%. A higher GDPpc suggested an increase in production, assuming that this increase involved a higher employment of workforce, thus a decrease of the unemployment rate. Regarding salaries, it was inferred that an increase in wages motivated the non-employed to enter the formal labor market, thus influencing the unemployment rate.

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High GDPpc group

For countries with higher levels of income measured in GDPpc, it was found that only the expenditure in education was not adequate for explaining the unemployment. As in the case above, both GDP and salaries had a negative relation with unemployment, in agreement with the results of the model, a 1% increase of the GDPpc increased the probability of reducing the unemployment by 9%, whereas a 1% increase in the salary raised the probability of reducing the unemployment by 2.5%.

The resemblance of the results between the Latin America sample and the high GDPpc sample helped to infer that the particular economic structure of the countries could lead to bias in the results. It was important to understand the limitation of the model in this regard, and for the analysis to separate the countries depending on their income measured as GDPpc.

In the model, S&T expenditure turned out to be statistically significant to estimate the unemployment levels, however the relation was inverse: a 1% increase of the expense in S&T increased the probability of reducing the unemployment rate by 0.57%. In those countries with higher income, where the investment in investment in S&T was higher, it was observed that increased productivity did not necessarily cause unemployment; on the contrary, productivity gains from innovation could probably turn into higher labor intake.

Lower GDPpc group

As for the countries in the sample with lower income, the findings of the model were that only GDPpc explained the unemployment rate, thus supporting the negative relation of these two variables, based on the estimation: a 1% increase of the GDPpc raised the probability of reducing the unemployment in 22%.

As expected, in countries whose investment in S&T was high, no significant impacts were seen on the unemployment rate. The probability was even less in countries with lower GDPpc. Based on these results it was deducted that public policies directed to promote investment in education or increasing wages would not have a significant impact on the levels of unemployment.

Additional analysis

The results were further analyzed by exploring the individual relation between unemployment and the expense in Science and Technology shown in Figure 6. The scatter plot 5a shows the correlation that exists in the countries with higher GDPpc, highlighting two trends. First, a high concentration of values was observed towards the left side of the graph, and secondly, a minor concentration of values to the right.

In the majority of the observations, no direct relation was perceived between S&T and unemployment. As for the second phenomenon, it seemed to validate that if the levels of investment in S&T increase, there is a minor decrease in the unemployment rate, as suggested by the model.

This behavior particularly matched the case of Brazil where there was a higher investment in S&T, high levels of production as seen in the GDPpc indicator, higher median wages and larger amounts invested in education that other countries in the sample. In sum, the application of these diverse public policy instruments might reduce unemployment.

On the other hand, Figure 6b shows the relation of both variables for the lower GDPpc group, minor increases in S&T expenditure did not seem to affect the level of unemployment of the sample. In this case, it is worth emphasizing that the lowest levels of unemployment related to the highest levels of expense in S&T were in Costa Rica, where the average percentage amount invested was larger than the average of the region. But this situation was not reflected in changes on the unemployment rate.

Figure 6. Relation between Unemployment and the expenditurein Science and Technology, 1996-2011.
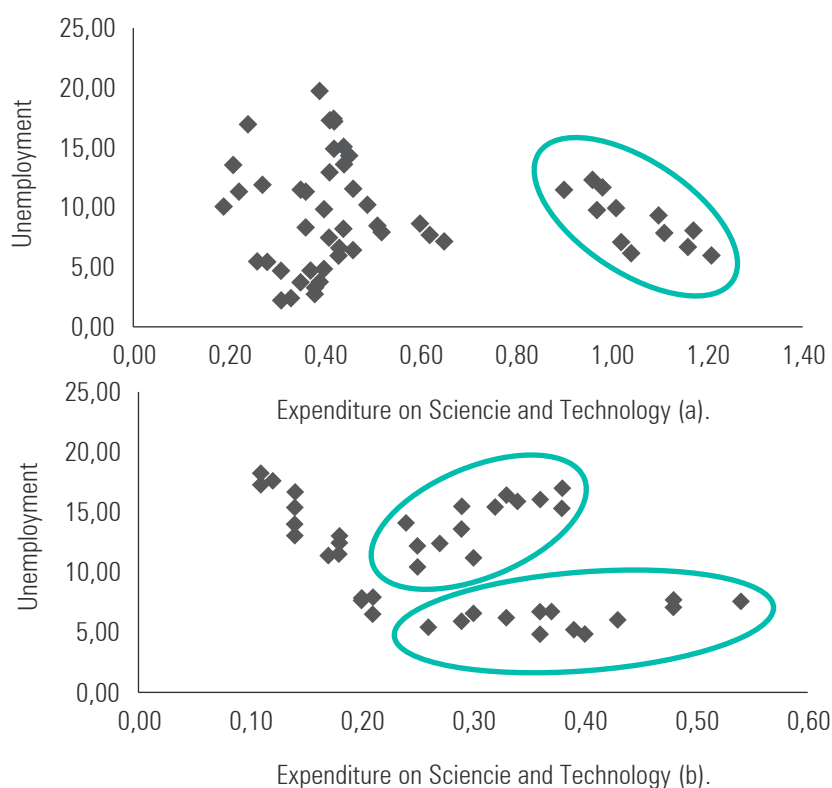
Source: Calculations by the authors based on the ECLAC data (2015)

In order to explain why some variables had to be excluded from the model, we estimated the Pearson correlation coefficients of independent variables in every group, to verify if the presence of linear correlation might explain these behaviors. In reality, as the Table 3 demonstrates, a high correlation exists between the expenditure in S&T and the expenditure in Education, mainly for the case of Latin America and the group of countries with lower GDPpc.

Table 3. Pearson correlation coefficients.

	Correlation	S&T	GDPpc	WAGE	EDU
Latin America	S&T	1,0000			
	GDPpc	-0,1276	1,0000		
	WAGE	0,1255	0,2830	1,0000	
	EDU	0,4184	-0,0157	0,1596	1,0000
Higher GDP	S&T	1,0000			
	GDPpc	0,1549	1,0000		
	WAGE	0,2676	0,2891	1,0000	
	EDU	0,1730	0,3158	0,1565	1,0000
Lower GDP	S&T	1,0000			
	GDPpc	-0,5133	1,0000		
	WAGE	-0,0561	-0,1270	1,0000	
	EDU	0,4742	-0,3787	0,2373	1,0000

Source: Summary of results. Calculations by the authors.

The interdependence seen in the expenditures in education and S&T demonstrated that the allocation of these expenditures seemed to be restrictive between these two activities (opportunity cost): in other words, if it was assigned to one, it would not be assigned to other. Therefore, public policies should be devised to promote the interrelation and synergy of funds allocation in these categories.

Accordingly, it is advisable for Latin American decision makers to formulate public policies and private sector initiatives to tackle the negative effects, minimize the risk and mitigate the political and economic consequences of potential massive unemployment (Marchant et al., 2014; Rodrik, 2015).

So far, three major ideas have been found in the literature. First, the creation of a system for Universal Basic Income in which eligible citizens are granted an amount of money unconditionally. Even though the policy idea was proposed some time ago, it is not until recently (after the 2008-2009 financial crisis) that it gained traction in public policy circles. Experiments on this matter are currently under evaluation in Canada and Finland (De Wispelaere and Stirton, 2004; Van Parijs, 2004).

Secondly, some suggest solutions based on the human capital theory, life-long-learning, retraining, upskilling and reskilling. These ideas are not particularly new but are definitely relevant in a contemporary debate about automation replacing jobs (Becker, 1962; Davis & Reeve, 2000; Cairo & Cajner, 2014).

Finally, the third option involves reducing the weekly working time: some European countries have taken the lead by reducing the weekly working hours and sharing work seems to be a fresh strategy to mitigate the unemployment wave predicted by the probabilistic models (Bosch & Lehndorff, 2001; Ohanian, Raffo & Rogerson, 2006; Askenazy, 2013).

Even though the model showed that investments in S&T did not affect the unemployment rate in the sample but contributed to labor productivity, it is important to devise, test and implement public policies and private sector plans that may contribute to mitigate the effects of innovation such as technological unemployment.

CONCLUSIONS

In recent years, countries in Latin America have increased their levels of investment in innovation, primarily through spendings on science and technology; however, the average investment levels remain low compared to the average level of S&T expenditure observed in developed countries. Worth noting cases such as Brazil and Costa Rica show that growth in S&T investment rates have followed the patterns of more advanced countries.

As noted in the data, countries with high levels of GDPpc in the region are still in the development stage in which S&T investments positively affect employment, attaining productivity gains. According to the model, it can be stated that promoting the development of innovations, alongside growth in salaries and increases in GDPpc could generate significant impacts on job creation, thus, reducing the unemployment rate. However, given the rapid evolution of technology observed in recent years, broad technological diffusion and the effects of globalization, it is crucial to question and forecast when the Latin American region will enter a productive stage in which there is a noticeable substitution of labor by capital.

The results of the model showed that the relation between the investments in S&T (in conjunction with the other variables) did not have a significant impact on the unemployment rate in the seven countries studied. Nevertheless, given the newest models proposed based on Frey & Osborne and the exponential growth of current innovations, further research is required on the subject of technological unemployment in the region.

Companies that have made significant investments in creating outsourcing services (Business Process Outsourcing, BPO) such as call centers would compete against technological innovations in speech recognition and real-time translation. The pervasive use of the Internet as a growing marketplace and a tool for trade could

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displace large number of people currently working in the retail sector, downplaying the role of the physical store and moving the workload to the development of digital content to become more attractive to consumers and increase satisfaction of delivery, that is, the logistics chain.

The projected effects that innovation and automation could generate in the labor markets of developed countries (unemployment) are a cautionary tale of what could tentatively and with a time lag occur in the region. The initial assumption is that tasks that require less formal education are the most automatable. However, recent reports showed that high-skill sectors such as finance have automated some of their operations (i.e. dark pools & high frequency trading) in which complex algorithms are involved in decision making for purchasing or selling securities at high speed.

The education variable did not prove significant in any of the models and its incidence on innovation is evidence that the substitution of labor by capital in our region was not present in the timeframe observed. Nonetheless, the literature offered tentative solutions through the human capital theory, upskilling and re-skilling of the workforce.

The initial considerations presented here about the relationship between technological innovation and unemployment seek to promote fresh research on this issue in the region, not only for academic purposes but also for the impact and implications for businesses and policy makers.

Employment is one of the most important subjects in business economics and if automation becomes the dominant form of production and value creation, this topic should lead to the formulation of tentative scenarios, the identification of unintended consequences (unemployment, crime, greater inequality) and the preparation of schemes to mitigate the adverse effects that can bring this transition to our society.

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