THE ELECTRIC REVOLUTION IN LATIN AMERICA

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Abstract

Latin America participated in the electric revolution which profoundly transformed the most developed Western economies between 1880 and 1930. The electrification of Latin America began relatively soon after these economies, but it was incapable of keeping up with them. Public electric lighting was introduced early in the big Latin American cities, where electric trams started running at almost the same time as in Europe, and electricity spread rapidly in the mining sector. In the most advanced countries or areas in the region, the manufacturing industry substituted the steam engine with the electric motor, following the example of industry in the United States and Europe. Nevertheless, towards 1930 electricity consumption per inhabitant for Latin America was far below that of the more advanced economies, and only the Latin American countries which lead the process of electrification had reached levels of electric consumption that were similar to those of the late industrialised European countries. One of the most striking features of the electric revolution in Latin America is rooted precisely in the enormous national differences. These differences are indicative of the great economic inequalities existing in the heart of the region and these nations' highly diverse capacity for economic modernisation.

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In the fifty years following 1880, a true *electric revolution* took place, profoundly transforming economic and social life in the Western World.[1] Electricity, first in the form of light from voltaic arc lamps, went from being a technological innovation - which drew the curiosity and admiration of the inhabitants of big cities - to becoming half a century later, a source of multifaceted energy (light, power and heat) that was increasingly associated with progress and modern life. Electricity was by then both a ubiquitous and increasingly indispensable good in homes, as well as in offices, shops and factories and in urban transport, public buildings and public spaces. Although around 1930 not at its full potential yet, electricity was already the general purpose technology par excellence, as no other to date, until the recent arrival of information technology. Without doubt, by 1930 the electric revolution had run its course, just as the industrial revolution had, spurred by the steam engine, a century before.[2]

How and when did Latin America become immersed in the electric revolution? Arguably, economic historiography has not yet considered this question. To find a historical interpretation or a temporal perspective of the electric revolution in Latin America, one has to go back far in time to when the process was as yet unfinished.

The US economic historian James Rippy maintained that Latin America participated punctually in the advent of the electric revolution, but was incapable of keeping up with the pace set by the industrialized countries. Latin America advanced so slowly that when the Great Depression started these countries were thirty years behind compared to the United States and the most developed European countries.[3] In a collective study of Latin America's industrializing progress with a sectorial focus, James Carson likewise maintains that Latin America began its electrification process early. However, according to this author, the introduction of electricity was promoted by European investors' interest in promoting electric trams, which meant that the spread of electricity was neglected beyond its use as a source of illumination.[4]

Sixty years later Carson and Rippy's complementary interpretations remain intact, since no author has been interested in empirically contrasting or challenging them with an alternative explanation.

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[1] I have borrowed the term 'electric revolution' from Hennessy, *Electric Revolution*, using it in the sense that he did. He was not the first author to use it. Long before, even at the time of the electric revolution, other authors used this expression.

[2] As is well known, industrialisation did not end with the industrial revolution. In the same way, the process of electrification did not come to an end with the electric revolution, rather, it continued for several decades more.

[3] Rippy, *Latin America*, pp. 208-16.

[4] Carson, 'Power industry', pp. 319-24. It should not be ignored that Carson was also a high-ranking executive of the *American and Foreign Power Company*, and, as such, his version is biased towards glorifying this company's contribution to the electrification of Latin America.

This paper takes on that challenge. It is structured in the following way. The first section, the introduction, outlines the principal characteristics of the electric revolution which began and developed in Europe and the United States between about 1880 and 1930. In the second part I make an analytical approximation of the beginnings of the era of electricity in Latin America and its different aspects and applications –lighting, traction, mechanical power, industrial heat and household appliances– making use of primary and secondary sources. The third part contains a new empirical contribution which aspires to define precisely how the process of electrification developed in all the Latin American countries. The paper closes with some final considerations as a form of conclusion.

I

Gramme's dynamo, a relatively simple but decisive technological innovation, spread between 1873 and 1874, triggering the electric revolution.[5] This machine easily incorporated improvements which quickly made it suitable as a commercial electrodynamic generator. In 1877, the Siemens company was able to start mass production, ushering in the generation of electric power –unlimited and cheap enough to be used for commercial purposes.[6]

The first of these was lighting. Voltaic arc lamps, in short series circuits, were installed during the second half of the 1870s in the main cities of the Old Continent and the United States. [7] The first electric locomotive was exhibited in 1879 at the Industrial Exhibition in Berlin.[8] In this same year, two other technological milestones were reached which can be seen to mark the foundation of the electric era. Edison invented the incandescent light bulb and in San Francisco the first power station in the world started operating.[9] A year later, Edison created an electric company in New York designed to provide the first centralized system of generation and distribution of electric power for public and private lighting using incandescent light bulbs[10]. The electric tram first appeared at the Paris Electric Exhibition in 1881 although, like the electric train, the innovation was not in fact developed until a few years later –1888 in the case of the tram and 1905, for the electric train.[11] A crucial new step forward was the presentation of long-distance transmission of electric power through

[5] Brittain, 'International diffussion'.
[6] Weiher and Goetzeler, *Siemens Company*, pp. 33-4.
[7] Bright, *Electric-lamp industry*, pp. 29-30.
[8] Machefert-Tassin, Nouvion and Woimant, *Histoire de la traction électrique*, p. 21; Siemens, *History of the house*, p. 85.
[9] Bright, *Electric-lamp industry*, pp. 67-74; Passer, *Electrical manufacture*, pp. 19 and 80-8.
[10] Passer, *Electrical manufacture*, pp. 89-90.
[11] Machefert-Tassin, Nouvion and Woimant, *Histoire de la traction*, pp. 21-4; Weiher and Goetzeler, *Siemens Company*, pp. 39-41 and 62.

high-voltage alternating current at the Frankfurt Electric Exhibition of 1891.[12] In the same year, in the United States an electric generator was tuned which was suitable for this system of current –three-phase alternating. From then on, hydraulic resources could be efficiently harnessed wherever they were located to produce electricity on a large scale and transport it to the big consumer markets, concentrated in urban centers. The first big practical application of the generation and long-distance distribution of alternating current was the Niagara waterfalls complex, for many years the biggest hydroelectric plant in the world, whose first phase was inaugurated in 1895. [13] In thermoelectricity, the key technological innovation was the steam turbine, designed by Parsons in 1884 and manufactured from 1896 in an improved version after a series of tests. The steam turbine, commonly known as the turbo generator or turbo alternator, depending on whether the current produced was direct or alternating, gave the dynamo a rotation speed considerably higher than that reached by applying a reciprocating steam engine directly to the dynamo. This permitted substantial saving in energy consumption and in the operating costs of the generator. Large electric power stations could therefore be built, making the most of the economies of scale and substantially lowering the unit costs of production, just as was achieved with the construction of the large hydroelectric plants.[14]

The most significant technological innovation was the electric motor. Electrical energy, with its unrivalled mobility and flexibility, makes the electric motor the most suitable for generating mechanical power for industry.[15] The construction of electric motors was not technically difficult once the production of dynamos had been mastered. However, the electric motor, operating with direct current had limited use because of the very short transmission radius of direct current. In 1888 Tesla invented the induction motor which was fed with alternating current, a key innovation.[16]

These technological elements shaped electricity's golden age of invention and innovation. It lasted scarcely two decades, concluding at the end of the twentieth century. The same cannot be said for the electric revolution. The most efficient systems of generation and transmission were developed very gradually, it took time for the electric motor to be adopted in many industrial

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[12] From 1885 both Westinghouse and Thomson-Houston had been applying distribution systems of alternating current for shorter distances using alternators and transformers which they had developed. This allowed them to offer lighting to small cities and scattered villages which could not be serviced by the technology of a system of low tension direct current initially established. Carlson, *Innovation as a social*, pp. 250-9; Siemens, *History of the house*, pp. 122-3; Weiher and Goetzeler, *Siemens Company*, p. 43; and Passer, *Electrical manufacture*, pp. 135-8 and 165-6.

[13] Passer, *Electrical manufacture*, pp. 284-94.

[14] Ibid, pp. 311-3. The construction of steam engines faced insurmountable economic limitations as from about 7,500 H.P. See Siemens, *History of the house*, pp. 222-30.

[15] Singer, *History of technology*, p. 231.

[16] Passer, *Electrical manufacture*, pp. 278-9 and 298-300.

activities which used the steam engine, the railways were electrified sparingly until the interwar period, and the industries which used electrolyte and electrochemical procedures also took their time. The beginnings of the era of electricity stretched over the last two decades of the nineteenth century and only in the first decades of the twentieth did it gain real importance in economic and social life, starting to contribute significantly, directly or indirectly, to the increase in the global productivity of the economies that adopted the new energy.

In industrialised economies, the sequence in the use of electricity went from lighting, to traction and, then, to providing industrial power. In places with significant water currents, there was a spurt of early electrification which predated the generalized use of electricity by industry, consisting in the electrolyte and electrothermal application.[17]

In Latin America, the initial electric development appeared to have taken another route, or, to be more exact, the sequence of application was different according to the country. Some, the most economically advanced, stuck to model of the innovating countries. The main cities of not so developed economies also tended to follow this model. However, in the most backward countries, electric lighting came via traction or mechanical force that was installed in mining or factory establishments or, alternatively, its use was restricted for a long time almost exclusively to the lighting of streets and houses. Finally, in the urban centres of some underdeveloped but dynamic economies, all the applications were introduced simultaneously. The electro-industries were barely present or rather they gained importance in specific places in a few countries, not so much because of abundant hydraulic resources but rather because of the opportunity of exploiting metallic minerals.

Of course, all of the above must be proved. Nevertheless, the documentary evidence for this is very weak as there is an almost complete absence of quantitative data on the production and use of electricity in most Latin American countries during this time and even until the mid-twentieth century.[18] Indeed, qualitative information on the establishment and initial development of electric companies established in many parts is also poor. Self-generators, about which we know even less, are not even mentioned, despite the fact that in some countries they generated more energy, or minimally less energy, than that provided to the public by electric companies. Given these conditions, in the following paragraphs, I will outline the inaugural moments of electricity, in its various uses, in the Latin American republics, without attempting to offer a complete picture. The knowledge we can glean from this type of approximation is limited, but it serves to illustrate some basic characteristics of the Latin American electrification during the pioneer period.

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[17] Bartolomé, *Industria eléctrica*, p. 14.

[18] ECLAC, *La energía en América Latina*; United Nations, *Estudios sobre la electricidad*.

II

In the late 1870s the first public demonstrations of electric light took place in those Latin American cities that were more dynamic and receptive to European and North American technical innovation. These demonstrations involved the installation of a circuit of electric arc lamps connected to a dynamo in a central place in the city. They took place in Havana in 1877, in Brazil in 1879, in Mexico in 1880, and in Caracas in 1883.[19] These public exhibitions of the qualities of electric light took place at almost the same time as those in France and England.[20] The inauguration of the first electricity generating systems for public services with more or less extensive distribution networks took somewhat longer to happen –though generally less than a decade. In 1882, London and New York boasted the first public electric systems in the world, while in Latin America these came into operation for the first time in various capital cities, in these respective years: Brazil and Chile in 1883, Costa Rica in 1884, Argentina and Peru in 1886, Mexico and Uruguay in 1887, Bolivia and Venezuela in 1888, Cuba and Panama in 1889, Colombia in 1890, and Ecuador in 1897.[21] With regards the most backward countries, Paraguay did not have electric public services until 1913, and nor did Haiti before 1912.[22]

It is interesting to note that in the ranks of these pioneering cities are some of the capitals of very backward countries. An example of this is the Bolivian capital, which was proud to be the third city in South America to have electric public services barely one year after Buenos Aires and one year before Havana.[23] This suggests that the launch date of public and private electric

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[19] For Cuba, see Mota, *Por primera vez*, pp. 8-14, and Altshuler, 'Impacto social'; for Brazil, *A energia eléctrica*, p. 34; for Mexico, De la Garza, *Historia de la industria eléctrica*, p. 17, and Liehr and Leidenberger, 'El paso de una free-standing company', pp. 272-3; in the case of Caracas, the illumination of statues started in 1873, and the first temporary system of electric arc lamps was installed in 1883. See Frank, 'Que se haga la luz', p. 245. For the South American countries in general, see CIER, *25 años*.

[20] Bright, *Electric-lamp industry*, p. 29.

[21] See Villalobos, *Historia de la ingeniería*, for Chile; Rohrmoser, 'Centenario de la electricidad', for Costa Rica; Galarza, *La industria eléctrica*, pp. 16-8, for Mexico; Altshuler and González, *Una luz que llegó*, pp. 209-23, and Altshuler, 'Impacto social', for Cuba; De la Pedraja, *Historia de la energía*, p. 100, for Panama; Velasco, *La fábrica de luz*, p. 4, for Bolivia; Camilo, *Historia de la Empresa de Energía*, p. 76, for Colombia; Frank, 'Que se haga la luz', p. 246, for Venezuela. For the South American countries in general, see CIER, *25 años*. With regards Paraguay, see also Halsey, *Investments in Latin America*, p. 312, and Herken, *Ferrocarriles, conspiraciones y negocios*, pp. 23, 32 and 106.

[22] 1912 saw the inauguration of the *Hatien Power Co.*, a company which was granted government permission to set up a power station for the application of motive power in various industries. See report in *Boletín de la Unión Panamericana*l, Feb. 1912, p. 207. I am not aware if this initiative was related in any way with the permission granted by the Haitian president in 1911 to the public limited company *Société Haitienne de Force Motrice* to set up electric power stations. See report in *Boletín de la Unión Panamericana*, May 1911, p. 846.

[23] Velasco, *La fábrica de luz*, p. 4.

lighting is not necessarily an indicator of the initial level of development of electricity, comparatively speaking. Not even is the corollary of this revealing in any way –that is, the first centralised electricity generating system was not up and running until relatively late (provided we do not consider beyond the early years of the twentieth century) because, as we can see, among the backward countries are economies which are comparatively advanced, such as Chile. A different case is that of those countries where the first public electric systems were established well into the twentieth century. It appears, as I have just pointed out, that this is what happened in Haiti and Paraguay, which is no coincidence, given that these are the most underdeveloped economies in the region. In Haiti the first power station started functioning perhaps as late as 1912. A year later, electricity was available for the first time in the Paraguayan capital thanks to investment by a British railway company.[24]

However, it is important to remember that the absence of power stations for public services did not necessarily mean the complete lack of electric lighting. It was not infrequent for mining and manufacturing companies producing electricity for their own consumption, to have surplus capacity and to sell excess energy to the local towns. This was quite common where mining was very important, such as in Bolivia and Mexico. In these countries, not only was electricity introduced for the first time by the industrial autonomous producers, but their contribution acquired considerable relevance before the first public service companies were set up.[25]

The initial period of electrification does not tell us anything about the intensity of its subsequent advance. In most places, progress was incredibly slow. But in others, complete systems (generation-transmission-distribution) were soon set up, which meant electricity spread quickly. This happened in the main city centres or conurbations of the region –in Buenos Aires, Rio de Janeiro, São Paulo, Montevideo, and Mexico City. The development of electricity in the metropolitan areas of the two big Brazilian cities and the Mexican capital was very intensive and occurred at the same time as in Europe. This was due to the presence in these cities of one of the international business groups with the greatest technical and financial capacity to make the most of the hydroelectric potential of the mountainous zones close to these conurbations.[26] But, it must be

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[24] See *The Electrician*, 3 Jan. 1913, p. 653; and 2 Jan. 1914, p. 548.

[25] For Mexico, Galarza, *La industria eléctrica*, pp. 9-14, and De La Garza, *Historia de la industria eléctrica*, pp. 18-21; for Bolivia, see CIER, *25 años*, p. 145-6. The Bolivian model of electrification is different from other countries that have a strong mining industry, such as Chile, Mexico and Peru. This is borne out by the fact that as late as 1930 the mining industry was responsible for 83 percent of electricity consumed in Bolivia.

[26] The history of the Canadian companies *Brazilian Traction, Light and Power Company* and *Mexican Light and Power Company*, and the fundamental role they played in the electrification of Brazil and Mexico is well known thanks to the work of Armstrong and Nelles, *Southern Exposure*, and McDowall, *The Light*. In 1937, the joint assets of both holdings, created by the same promotors, amounted to 535 million dollars (book value), slightly exceeding the assets of

added that, unlike in Europe, accelerated growth was not confined to those urban areas where conditions most favoured the hydraulic model of electricity production; it also occurred in certain towns which used the thermal model (coal), such as Buenos Aires and Montevideo.

The electric tram represented the first large-scale application of electricity as motive power. In 1888 the United States witnessed the innovation –the Sprague system– which marked a technical watershed and heralded an astonishing expansion of this new means of transport. The electrification of the trams advanced so rapidly in the United States that it took just over a decade to complete.[27] The most industrialised European nations advanced at a far slower pace. In Great Britain and France the boom occurred in 1895, and the process of electrification had not yet finished by 1913, whereas in Germany progress was faster, midway between that of the United States and the other European powers.[28] On both sides of the Atlantic, the rapid spread of the electric tram greatly boosted the growth of built-up areas and contributed to the industrial boom of that period.

In Latin America the same phenomenon occurred somewhat later and certainly with less intensity. In Brazil the first electric tram circulated as early as 1892 in Rio de Janeiro, although its other cities lagged behind.[29] In Argentina, the first electric tramline started running in Cordoba in 1898.[30] The following year Chile started using electric traction.[31] In 1900 the first electric tramline was inaugurated in Buenos Aires, in Mexico City and in the bay of Havana.[32] In the first decade of the twentieth century, this new means of transport made its appearance in the rest of the big cities of the continent, as well as in many other cities.[33] However, the question that immediately comes to mind is: How long did the switch to the electric traction system take?

In this regard, I can state that in the case of Argentina the electrification of the trams was already practically completed in 1914.[34] But this was definitely

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the Latin American electric companies belonging to *American and Foreign Power Co.* No other group of electric companies in the world was comparable in size to these three holdings. See Hausman, Hertner and Wilkins, *Global Electrification*, p. 218.

[27] McKay, *Tramways and Trolleys*, p. 47-51; Machefert-Tassin, Nouvion and Woimant, *Histoire de la traction électrique*, pp. 51-8.

[28] Byatt, *British electrical industry*, p. 28-32.

[29] In São Paulo trams were first used in 1900, while in the capitals of the northern states they only came into use in the 1930s. See *A energia elétrica*, pp. 35 and 45.

[30] Rippy, *Latin America*, p. 209.

[31] CIER, *25 años*, p. 210.

[32] Halsey, *Investments in Latin America*, pp. 483-4; De La Garza, *Historia de la industria eléctrica*, p. 18; Liehr and Leidenberger, 'El paso de una free-standing company', p. 269; Altshuler, 'Impacto social'.

[33] Rippy, *Latin America*, p. 209.

[34] According to my calculations, based on the data contained in Argentina. Comisión Nacional, *Tercer censo nacional*, in 1914 electric tramlines made up 99.3% of the total in Argentina, in terms of both passengers transported and kilometres covered.

an exceptional case. Even in Montevideo, which headed up the process of electrification in the subcontinent, at the end of World War I had not yet withdrawn its mule-drawn trams.[35] By that time, in the Chilean cities with trams, including Santiago, there were still a number of mule-drawn companies and lines.[36] The same occurred in Ecuador.[37] The small, most backward countries like Guatemala only had trams in the capital and had not yet begun electrifying them, or had just finished electrifying them, such as Paraguay; or did not even have tramlines, like in Honduras.[38]

The electrification of the railways took much longer than that of the tramways in Europe and the United States –and this was not exactly due to the greater length of the railway lines. The shift to the electric train started there between 1890 and 1910 in suburban trains (surface, underground and elevated trains), since steam trains were not capable of handling these train routes with their high volume of traffic and the demands of rapid acceleration and deceleration. In the medium and long-distance lines, electrification progressed more slowly, except for interurban trains which dealt with high volumes of traffic.[39]

In Latin America the first suburban electric train was inaugurated in Argentina in 1916, although three years before in Buenos Aires the first section of underground railway started functioning.[40] The opening of the first interurban railway line took place in 1912 in Cuba.[41] The following lines opened a decade later, despite the fact that for some time several governments in the region had been seriously studying the drawing up of a program of electrification.[42] In Brazil, the first electrified line came into service in 1921, while in Chile this only happened two years later. In 1925 Mexico joined them, with the opening of a section of the line joining the capital to the port of Veracruz.[43] In the mid 1920s none of the other sixteen remaining republics had yet managed to electrify even a section of a line. And although some lines were added or more sections electrified at the end of the 1920s in Argentina, Brazil, Chile, and some other countries too –such as Costa Rica and Venezuela–, in

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[35] Smith, *Electrical goods in Argentina*, p. 86.

[36] Smith, *Electrical goods in Bolivia*, p. 57.

[37] Halsey, *Investments in Latin America*, p. 290.

[38] Ibid., pp. 409 and 425; reports in *The Electrician*, 3 Jan. 1913, p. 653; 28 Nov. 1913, p. 346; and 6 Mar. 1914, p. 920.

[39] Duffy, *Electrical railways*, pp. 16-27. In the case of underground lines, steam trains were discounted from the start (1890, in London), for reasons of public health.

[40] *The Electrician*, 1 Sep. 1916, p. 750; Halsey, *Investments in Latin America*, p. 75.

[41] Not taking into account the short section of a private mining line in Bolivia. See Machefert-Tassin, Nouvion and Woimant, *Histoire de la traction électrique*, pp. 450-1.

[42] In 1903 the Chilean government named a commission in charge of preparing a plan of electrification, but this was not approved until 1918 and its execution only began three years later. See report in *Commerce Reports*, 19 May 1921, pp. 1016-7.

[43] *Revista internacional de Dun*, July, 1925, pp. 43-7, and Feb. 1926, pp. 54-5.

1930 and even in 1940 this added up to just a few hundred kilometres of line.[44] In short, the electrification of rail transport was postponed until later.

In regard to the application of electricity as industrial power, between 1880 and 1930 in the United States, the generation of mechanical power shifted from hydraulic prime movers and steam engines to electric motors, thus saving energy and significantly increasing productivity.[45] However, the real takeoff in the United States did not happen before the turn of the century. Even in 1899, electric motors only accounted for 5 percent of the industrial mechanical power. A decade later, this percentage had jumped to 25 percent, in the following decade (1909-1919) there was a preponderance of electric motors and this went from strength to strength throughout the 1920s.[46] In other industrialised countries we observe a similar takeoff in the first decade of the century and a strong acceleration in the second. This meant that once the World War was over, electricity became the main motive power for industry (as well as being a source of light and heat).[47]

It is very difficult to know whether Latin America advanced at the same pace as the more developed economies. Let me clarify that I am referring to the change in the energy source, not the magnitude of mechanical power used by industry. As is well known, during this period Latin American industry was still poorly developed. Access to industrial censuses is essential to be able to determine the absolute and relative importance of electricity as the motive power of industry. Unfortunately, due to the complexity and cost of conducting censuses for public administrations with meagre resources, most Latin American countries did not carry them out until later.[48] Those countries which conducted industrial censuses before the World War II included the following: Argentina in 1895, 1914 and 1935, Brazil in 1907 and 1920, Chile in 1894, 1911, 1928 and 1937, Mexico in 1930 and 1935, the Dominican Republic in 1937, Uruguay in 1908 and 1930, and Venezuela in 1936.[49] What is more, some of

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[44] Machefert-Tassin, Nouvion and Woimant, *Histoire de la traction électrique*, pp. 450-1.

[45] Devine, 'From shafts to wires'.

[46] DuBoff, *Electrical power in American manufacturing*, pp. 31-2. According to Devine, 'From shafts to wires', electricity did not revolutionise the industrial organization system of the United States until the first decade of the century.

[47] In 1907 in Great Britain, electricity only made up about 10 percent of the industrial power, whereas in 1924 it had increased to 50 percent. In Germany, around 1907, electric motors already constituted about 22 percent of the mechanical power. See Byatt, *British electrical industry*, p. 73-83. In 1929-30, the percentages in all the developed countries of Western Europe were above 70 percent, except for Great Britain (66%) and France (49%). See Segreto, 'Aspetti e problemi dell'industria', p. 350.

[48] The following countries did not carry out censuses until after the World War II: Bolivia, Colombia, Costa Rica, Cuba, Ecuador, El Salvador, Guatemala, Haiti, Honduras, Nicaragua, Panama, Paraguay and Peru.

[49] This does not take into account censuses that were partial or with extremely scant information about the stock of industrial motors. There is much more information available for Chile than for other countries. This is because for many of the years subsequent to 1906, tabulated data

these censuses provide data that is of little use to us, since they only record the value of electricity consumed by industrial establishments. In the other censuses, with few exceptions, no distinction is made between prime movers, electric generators or electric motors, making it impossible to accurately assess their relative weight within mechanical power used by industry.[50] With all of these provisos, it is hardly surprising that we can only trace sporadically and approximately, the progress in electricity use by Latin American industry for a few countries and for specific years.

The electric motors used in 1914 in Argentina by the entire secondary sector (mining and quarrying, manufacturing and 'non-factory' industries) were of approximately 84,790 H.P., which represented at least 30 percent of the total motive power.[51] In 1935 electric motors totalled 713,932 H.P., which meant that their power grew at an average annual rate of 10.7% in the two decades between 1914 and 1935. In 1935 electric motors already represented just below 70 percent of industrial mechanical power.[52]

In Brazil, the use of electricity in industry had only recently started in 1907: electric motors had combined power of 4,687 H.P., thus accounting for about 5 percent of the total motive power.[53] There was, however, spectacular progress between 1907 and 1920 when electric motors made up 167,118 H.P. So,

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from the official records of industrial and mining companies were published in the Statistical Yearbooks and the *Sinopsis*. This information really was a virtually continuous pseudo-census.

[50] Prime movers are machines which transform energy from different sources (water, wind, steam, etc.) into mechanical energy. Electric generators are energy convertors which, driven by prime movers, transform mechanical energy into electrical energy. Electric motors are machines which transform electrical energy into mechanical energy. What we must compare is the nominal power of electric motors with prime movers, excluding those used to drive electric generators or those in reserve. But the censuses prior to 1939 rarely provide detailed information on prime movers, leading to an underestimation of the relative importance of the electric motors. There is a detailed examination in IBGE, *O censo industrial*, of the potential and shortcomings of the industrial censuses carried out by Latin American countries between the late 1930s and the late 1940s.

[51] The figure indicated includes electric motors used by non-electric public service companies, but, without doubt, the consequent calculation error (upwards) is more than compensated (downwards) by the comparison with the total number of prime movers. See the previous note and Argentina. Comisión Nacional, *Tercer censo nacional*, pp. 105-6. The conversion factor between H.P. and kW is 1 kW = 0.7457 H.P. See United Nations, *Energy statistics*, p. 42.

[52] The results of the industrial census of 1935 did not provide precise information on the prime movers, or at least, this is not reflected in the publication used, see Argentina. Dirección General de Estadística de la Nación, *Estadística industrial de la República Argentina*, p. 74. This publication does, however, provide data on the power of the electric motors, classifying them into those fed by a bought current and those fed by a current generated by own facilities, the former making up 72.4 percent of the total. My calculation slightly exaggerates the relative importance of electric motors by disregarding the prime movers which contributed mechanical power directly to the machines of industries.

[53] The aggregate power of all the motors was 109,284 H.P. See Centro Industrial do Brasil, *O Brasil. Suas riquezas naturaes*, p. 148.

for around 15 years the power of industrial electric motors grew at an annual rate of 31.7 percent! Thanks to this, in 1920 these motors were already predominant: contributing 53.8 percent of motive power.[54]

It is very interesting to compare the situation of Brazil with that of Chile and Uruguay at the beginning of the century. In 1908, Brazil and Uruguay conducted their first industrial censuses at practically the same time, while in Chile a statistical inventory, which can be considered as an industrial census, took place in 1906.[55] Despite the enormous size difference compared to Brazil, Uruguayan industry had more electric motors (5,817 H.P.) and these contributed approximately one-fifth of the industrial mechanical power.[56] Chile on the other hand had only 2,392 H.P. in electric motors, its relative weight (8.7 per cent) positioning it closer to Brazil than to Uruguay in terms of the application of electricity in industry. But the new source of mechanical energy spread quickly in 1910s and 1920s. In 1914, the Chilean industry used electric motors with strength of 11,622 H.P. This represented an annual increase rate of 21.8 percent from 1906 and, in addition, that electricity was already providing at least 28.1 percent of industrial mechanical power, that is, a ratio similar to that of Argentina at the same date. The electrification of Chilean industry continued during the war, although not at the same pace. In 1920, the strength of industrial electric motors rose to 26,653 H.P., an annual increase rate of 14.8 percent from 1914 –growing to represent at least 32.7 percent of industry's motive power.[57]

The above data create a picture that invites optimistic conclusions. In the most important South American countries, in terms of size or level of economic development, exploitation of electricity by industry (and mining) took off just a decade later than in the leading economy, the United States. Electricity appears to have spread in the 1910s and 1920s at almost as intense a pace as that of the

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[54] Brazil. Directoria Geral do Brazil, *Recensamento do Brazil*, pp. 72-87. The census distinguishes among electric motors according to whether or not they are driven with power generated by own facilities.

[55] Chile. Sinopsis estadística, *Sinopsis estadística*. The statistical summaries for different years and the statistical yearbook volumes about manufacturing and mining and metallurgical industries of the Annual Statistics (*Anuario Estadístico*) contain the usual census information but do not count equipment in machinery and motors of the 'small establishments and workshops'.

[56] The power of all the motors, including those used to produce electricity in own establishments, rose to 34,510 H.P. See Uruguay. Dirección General de Estadística, *Anuario Estadístico*, p. 1209.

[57] Official statistics give higher total figures for the manufacturing industry because they include power plants, whose motors, I have, of course, excluded. The great importance of electric motors used by mining must be borne in mind, both because of the mining sector's substantial importance as well as its intensive use of electric motors. Unfortunately, mining statistics only have detailed data on the copper subsector, where, in 1915, the strength of electric motors was 66,042 H.P., equal to 92 percent of the total. See Chile. Sinopsis estadística, *Sinopsis estadística*; and Chile. Oficina Central de Estadística, *Anuario estadístico. 1914*, p. 43; idem, *Anuario estadístico. 1915*, pp. 31-2; idem, *Anuario estadístico. 1920*, p. 31.

United States. Consequently, around 1930, electricity had replaced other sources of mechanical energy in most industrial activities. However, it is evident that the universalisation of electricity in the Southern Cone cannot be divorced from its poor endowment of coal, in contrast with the United States. It is also true that the industrial use of electricity in both zones of the Western Hemisphere cannot be compared if, instead of considering the importance of electric motors among total motors, we consider their power, both in absolute values as well as per inhabitant.[58] Even more importantly, the assessment is optimistic because it is based on very partial empirical evidence, which does not include economies whose industrial sector was less dynamic and less developed.

In relation to the electro-industries in 1913 in a few Latin American countries the first ones had already taken root in steel and copper production. The first electro-industry was steel manufacture using electric furnaces. At this time there were two electric steel mills in Mexico and one in Brazil.[59] In Brazil, as a result of World War I, some more steel mills were built and there were various attempts, apparently futile, to set up electro-chemical industries.[60] On the other hand, a powerful industry of copper production through electrolysis emerged in Chile in 1913. However, the successful development of the copper industry was not imitated by other industrial activities.[61] Nor did these industrial activities develop in the other economies. By the end of World War II, neither in Argentina nor in Mexico, had a chemical or metallurgical industry emerged yet. These industries, because of their extremely high energy consumption, would have installed their plants near large hydroelectric plants.[62]

In regard to household appliances they appeared after the pioneer period of the era of electriciy, once the electric motor had been perfected. In the initial years of the twentieth century the fan, the iron, the vacuum cleaner, the stove and oven, the heater, the fridge and the washing machine made their

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[58] To give an example, according to my calculations in 1919-20, while the United States had 14.8 H.P. of electric motors for every 100 inhabitants, Brazil only had 0.6 H.P. Given that the United States was leading industrial power in the world and the Latin American countries' economies were not industrialised, this could not have been any other way.

[59] Bartolomé, *Industria eléctrica*, table 3.4., p. 61.

[60] See report in *Revue générale de l'électricité*, 2 Feb. 1924, p. 35 ; Smith, *Electrical goods in Argentina*, pp. 103-4.

[61] The metallurgy of copper became extremely relevant in electricity consumption. In 1929 electric generators which almost exclusively provided for the energy needs of the copper companies (mining and metallurgy) were of 184,935 KW, which was equal to approximately 62 percent of the total electricity generating capacity of the country. See Chile. Dirección General de Estadística, *Estadística anual*, pp. 15-6.

[62] For Argentina, Sintes, *La electricidad en la industria argentina*, pp. 63 and 107; and, for México, Alanís, *La energía en México*, pp. 39-40.

appearances. All of them were commercialised before 1914.[63] However, in the 1910s these appliances (except for the electric iron) were luxury goods even in the United States, which took the lead from the start.[64] They became popular very quickly after the World War.[65] So much so that in the 1920s, the prevailing opinion in business circles was that the quantity of household appliances purchased by the population constituted, together with the level of electricity consumed per inhabitant, a reliable measurement of the state of electric development reached by a given country.[66]

In Latin America, the spread of household appliances was limited until at least, the Great Depression. The main factor constraining the consumption of household applicances was the price of electrical energy in relation to that of domestic labour. If in the United States household applicances became popular quickly from the time of the World War, it was precisely because of this labour-saving element. Labour tended to become markedly more expensive. By contrast, in Latin America, the situation was quite different, as was reiterated in many reports published during this time. Here, for example, is the opinion of an official North American report on the state of the Chilean market:

> 'There is a plentiful supply of household labor available, and it is, in general, considered fairly efficient. Few of the servants are accustomed to modern methods of performing their duties, however, and if supplied with electrical household appliances a considerable amount of supervision would probably be necessary (…) Consequently, labor-saving devices have not had the same appeal in Chile as in those countries where the housewife does a considerable amount of the work incident to the upkeep of the home.'[67]

The arguments expressed here are perfectly applicable to any other Latin American country, on the basis of judgements expressed by contemporary experts.[68] Despite powerful advertising campaigns by manufacturing companies, while the servants' salaries remained low, only modest progress in the widening of the markets of the most developed Latin American countries

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[63] Hennessy, *Electric revolution*, p. 16.

[64] Platt, *The electric city*, pp. 154-5.

[65] In 1929 in the Chicago area, 95 percent of the clients of the electrical companies owned an electric iron, 87 percent had a vacuum cleaner and 53 percent a radio. Ibid., p. 251.

[66] U.S. Department of Commerce, *Central lights and power plants*, p. 12; and *Commerce Reports*, 15 Nov. 1926, pp. 405-6.

[67] U.S. Department of Commerce, *The electrical equipment market in Chile*, p. 10.

[68] More testimonies in this line can be found in reports in *Commerce Reports*, 14 Dec. 1925, p. 646; 9 Apr. 1928, p. 97; 30 Apr. 1928, pp. 292-4; 7 Oct. 1929, p. 44; and U.S. Department of Commerce, *Central lights and power plants*.

could be expected.[69] However, a significant drop in the electricity rate alone could considerably encourage the use of household appliances even in the poorest economies of the region, such as Haiti, where 90 percent of the population did not have any household appliances, and in the homes of the more affluent families the only appliances were irons and fans.[70]

III

The facts and figures presented above give some idea of the chronology and the intensity of the spread of electricity throughout the region. Naturally, in order to gain more in-depth and precise knowledge of the subject we need systematic information about the production and consumption of electricity (ideally, according to types of uses) or, in the absence of this, information about the load capacity of the power stations. However, in almost all the countries, there is simply no information prior to the 1930s, and for a considerable number of countries, there is not even information before the 1940s or before 1950. In the absence of these basic data, we have no option but to resort to importations of electric equipment. Concretely, I propose that we resort to the exportations of this type of material to Latin American countries by Germany, Great Britain and the United States (to abbreviate, the G-3). Below, I try to justify the following to some extent: firstly, that importations are a good proxy for expenditure on electrical equipment; secondly, that the exportations of the G-3 are a reasonable approximation to total importations, for this type of goods; and, thirdly, that the accumuated expenditure on electrical equipment is clearly related to the degree of electrification reached by the Latin American nations.

With regards the first argument, it is worth mentioning that all the indicators we have point to the fact the Latin American electrical manufacturing industry had not yet started, or, at most, was still in its very initial phase. The experience of the bigger, more developed economies in the region bears witness to this. In Argentina during the Great War a few production lines sprang up, producing simple electrical material, such as cables, and a company was created to supply components for the equipment of electric power stations.[71] During the War Brazil also began to manufacture some components of electrical material and equipment, such as cables, insulators and low power engines. Nevertheless, production was small-scale until the late 1920s, which led specialists of the

[69] Report in *Commerce Reports*, 9 Apr. 1928, p. 97. The gigantic holding *American and Foreign Power Co.* invested substantially in marketing and advertising campaigns aiming to create a market for household appliances. See Wilkins, *Maturing of multinational enterprise*, p. 133.
[70] See reports in *Commerce Reports*, 14 Dec. 1925, p. 646; and 30 Apr. 1928, p. 293.

[71] The *Compañía Industrial de Electricidad* manufactured several accessories needed for the big power station built in Buenos Aires by the new *Compañía Italo-Argentina de Electricidad*. See report in *The Electrician*, 1 Dec. 1916, p. 300; see also Smith, *Electrical goods in Argentina*, pp. 16-7.

period to conclude that this industry was still in its initial phases.[72] At the end of the first republic era, the Brazilian economy remained almost entirely dependent on the importation of the electrical material it needed.[73] The first industrial census carried out in 1929 in Mexico records a minute sector of companies involved in the manufacture and installation of electrical material.[74] Chile, one of the countries which before the Great Depression had made most progress with its industrialisation, did not have an electro-technical industry.[75] Cuba did not have one either.[76] The same applied, of course, to Central America.[77]

Let us move on to my second point. We know that the electro-technical industry of Germany, Great Britain and the United States dominated world exportations during the period of the electric revolution. The share of these three countries remained at over 80 percent.[78] In Latin America, the hegemony of the four industrial groups of these industrial powers was more overwhelming than in other markets. The four groups are: General Electric of the United States and also in Great Britain with Thomson-Houston (a subsidiary of General Electric); Westinghouse of the United States and in Britain through the subsidiary company; AEG, of Germany; Siemens of Germany and in Great Britain through its subsidiary.[79] The two giants of the German electro

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[72] Report in *L'Électricien. Revue Internationale de l'électricité et de ses applications*, 1 Jul. 1926, pp. e-320-1. According to an official North American report, production began in 1926 and for years it expanded slowly. See U.S. Tariff Commission, *Mining and manufacturing industries*, p. 60. A decade before 1926, *General Electric*, overwhelmed by problems with maritime transport, started to manufacture light bulbs in Brazil. See Wilkins, *Maturing of multinational enterprise*, p. 28. According to Wilkins, North American investments had a hand in the advent of the almost irrelevant electro-technical industry of Latin America in the 1920s. Ibid., p. 72.

[73] CIER, *25 años*, p. 157.

[74] The 8 establishments dedicated to the 'fabrication and installation of electric devices in general' employed 60 operators and used a motive power of 76 horsepower. See Mexico. Dirección General de Estadística, *Primer censo industrial de 1930*.

[75] See report in *L'Électricien. Revue Internationale de l'électricité et de ses applications*, 15 Apr. 1925, p. e-194 ; and U.S. Department of Commerce, *The electrical equipment market in Chile*, pp. 22-3.

[76] See report in *Commerce Reports*, 4 Apr. 1932, p. 45.

[77] For Guatemala, see report in *L'Électricien. Revue Internationale de l'électricité et de ses applications*, 1 May 1925, p. e-221 ; for Costa Rica, *L'Électricien. Revue Internationale de l'électricité et de ses applications*, 15 May 1928, p. e-255.

[78] The market shares of the three vary substantially if they are considered individually but not if they are taken together. Until 1914 Germany dominated the field most notably. After this it was displaced by the United States because the German producers lost control of the Belgian and Swiss holding companies which financed the electric companies. See Hertner, 'German multinational enterprise', p. 125; idem, 'Financial strategies and adaptation', p. 153.

[79] The subsidiaries of General Electric (British Thomson-Houston), Westinghouse and Siemens were the main manufacturers of electrical equipment in Great Britain. In the decade prior to the World War the British electro-technical industry threw itself into production for foreign markets, of which Latin America was of notable importance. See Byatt, *British electrical industry*, pp. 2, 152 and 168-70.

technical industry (A.E.G. and Siemens) built a network of subsidiary companies to sell their products. They established this network in nearly all of the Latin American markets.[80] The German, American and British electro-technical industry certainly did not monopolise the entire international market. Some companies from other very technically advanced European nations (Switzerland, France, Italy, and Sweden) were able to offer high quality, reliable equipment by specialising in certain types of goods. Thanks to this they controlled small segments of the Latin American markets.[81] However, G-3 exports represented such an important portion of Latin America's foreign purchases of electrical material, that we can be reasonably sure that G-3 exports provide a reasonably accurate picture of Latin American imports, just as occurs with transport equipment and machinery.[82]

Before examining the series of imported electrical equipment, we still need to resolve one unknown element: to what point does the value of this material reliably reflect the level of electric development reached? I have indicated that we do not know the magnitudes of the production and consumption of electricity. Nor do we know how the total load capacity of the plants evolved - we do not even know what it measured. Even so, we can estimate approximately, with a tolerable margin of error, what this total load capacity was at a national level in 1930 (see table 1). So, when we compare the data of both variables –the accumulated importations of electric goods between 1891 and 1930, and the total installed capacity in 1930– we discover that they are closely related (figure 1). In view of the figure, I believe any doubts are dispelled regarding the virtue of the G-3 exportations of electrical material as an indicator of degree of electrification reached by the Latin American countries. Both variables appear to be closely correlated in an exponential function. The correlation is good enough for us to be able to detect that certain value pairs which stray off the projected level are certainly the result of estimation errors. In the case of Bolivia and Paraguay there is no doubt that my aggregates of electrical goods considerably underestimate the imported volumes. By contrast, the divergences of Venezuela and Ecuador would be attributable to an undervaluation of the total load capacity. I have no explanation for the only other significant divergence – Costa Rica.

< table 1>

[80] Rippy, 'German investments in Latin America'; Young, 'Los bancos alemanes y la inversión directa', pp. 114, and 116-7.

[81] Broder, 'Multinationalisation of the French electrical industry', pp. 184-5; Hertner, 'German multinational enterprise', p. 125; and report in *Commerce Reports*, 25 May 1925, pp. 462-3.

[82] Towards 1928, electro-technical products of Germany, Britain and very strikingly, the United States, shared virtually the entire Latin American market. See Segreto, 'Aspetti e problemi dell'industria elettrica', p. 380. For transport equipment and machinery, see Tafunell, 'La inversión en equipo de transporte'; idem, 'Capital formation in machinery'.

<figure 1>

As just indicated, I propose an approach to total Latin American importations of electrical equipment and material based on the exportations of the three main suppliers. I used the same method in previous studies to estimate investment in equipment goods. This elaboration is not without its limitations and difficulties, as I have described in detail in these papers.[83] One of the limitations stems from the fact that the sources do not permit us to go back further than 1891. It is even highly dubious that in the first few years after 1891 all electrical equipment exported is recorded.[84] In any event, these possible initial shortfalls disappear after a few years, so that the long series contained in table 2 give, according to all indicators, a reasonably close depiction of reality.

<table 2>

Table 3 translates the series from the previous table into growth rates in the various historical sub-periods, thus making it possible to discover the different paces of the process of electrification, over time as well as among countries. Let us begin with the former. Expenditure on electrical equipment expanded at a rate of almost 8 percent annually for the four decades identified as the era of the electric revolution. It is a typical rate for an emerging activity with huge growth potential, and which is leading a profound economic change. But the ascent was not steady: Latin America progressed more rapidly before World War I, particularly between 1901 and 1913. In this long, prodigious decade in Latin America, the incorporations of electrical equipment grew at an annual rate of 21.8 percent, that is, they increased tenfold. They subsequently suffered a sharp contraction, as a result of supply problems related to the war. The recovery, which started in 1920, was only completed in 1924, when the prewar levels were exceeded. In the ten postwar years (1921-9) electricity in Latin America developed at a great speed, although not as rapidly as in the century preceding the war.

<table 3>

[83] In Tafunell, 'Capital formation in machinery', I explain the methodological problems that the G-3 statistics present for quantifying exportations of electrical goods, as well as options I used to resolve these.

[84] The United States foreign trade statistics provide no information on electrical material until 1891, not specifying the nature of this material or making any type of distinction until 1909. In the early 1890s German and British statistics it was not recorded separately except for telegraphic and telephony material.

The national differences are much more notable than those recorded between different stages in the whole of the region. The diversity is too big to condense into a few lines, which is why I shall stick to a description of the national trajectories which most deviated from the general pattern.[85] The biggest success cases are Argentina and Chile, which show a dynamism that is clearly superior to the rest, except during the war period. The Dominican Republic is a somewhat dubious case of success, matching Cuba in its atypical evolution during the first thirty years of the twentieth century. Colombia, like Venezuela (to a lesser degree) and Ecuador (even less so) stood out thanks to the boost as from the prewar years. At the other extreme is Haiti, some of the Central American countries (El Salvador and Guatemala), and Brazil – surprisingly enough. The reason for the electrical backwardness of the first two cases compared with Honduras and Nicaragua is not evident, although it is quite understandable that Costa Rica should head this group, given its level of relative economic prosperity within the Central American region. In the case of the South American giant, Brazil, its slow progress in the 1890s and its recession during World War I watered down excessively its performance overall.[86] If we turn our attention to the peak, most promising period (1901-13), we find Chile, Brazil, Uruguay and Argentina in the leading positions. In the second big electrification spurt (1921-9), a handful of backward countries, such as Venezuela, Ecuador, Haiti, Guatemala, El Salvador and Nicaragua, jumped ahead of the fastest countries, also overtaking some of the countries with the greatest electrical development –Costa Rica, Argentina and Uruguay. It would certainly be out of place to conclude this brief interpretation of table 3 without making reference to the two great republics, Mexico and Peru. They have not been mentioned until now because their cases go unnoticed. Mexico shows a low-profile evolution, which does not fit in well with what emerges from historiography. This is, without doubt, because historiography has considered and emphasised the electrification of Mexico out of its regional context. The participation of Peru in the two phases of greatest acceleration in the electrification race was discrete.

When exploring this subject, no matter how superficially, we cannot avoid comparing the national investment levels in electrical goods. This comparison makes real sense economically if it is normalised by population, given the very different sizes of the Latin American countries in geographic, economic and demographic terms. Table 4 shows the results of two cross

[85] Leaving aside Bolivia and Paraguay, as well as Panama (not even present in the table), given that their evolution is distorted (at least in the first 20 years) by a notable underestimation by the G-3 of their importations (an extreme overestimation, in the case of Panama).

[86] The relatively weak expansion in the 1890s is related to the unusually heavy investment in telegraph or telephone networks at the beginning of the 1890s.

sections at the beginning and the end of the period studied, as well as a for the entire period.

<table 4>

The countries are arranged hierarchically according to their position in the entire period (average of the years 1891-1930). Argentina and Cuba, neck to neck, stand out from the rest with their expenditure on electrical equipment per head nearly tripling that of Latin America. Chile appears in third place, followed by Uruguay in fourth, both with levels that double the regional average. Costa Rica is the only other country that acquired more electrical goods per capita than the average of Latin American countries. Mexico, in sixth position, was at 74, and Brazil, seventh, with 67. The next country, Venezuela, is at below 60 per cent of the regional level, while Peru and the Dominican Republic were at around 50 per cent. The remaining countries were at less than half of the regional average.

The positions in the initial decade of electricity were very similar in most cases. However, a minority was located at a much higher position. Such was the case with Costa Rica and Brazil, which showed precocious electrical development. With nuances, this could be applied to Guatemala, in spite of it being situated below the Latin American average.

The relative positions in the final years of this period (1928-30) allow us to take stock of the degree of development reached by each nation, from a regional perspective. Chile, Uruguay and Venezuela moved up strongly, whereas Colombia advanced without managing to free itself of its status as a backward country. Others moved in the opposite direction. The most spectacular cases of loss of dynamism are those of Cuba, Costa Rica and Brazil, though it must be specified that, in view of their records for the whole of the 1891-1930 period, we can infer that Cuba, and to a lesser degree, Brazil only advanced more slowly than the rest towards the end of this period. The situation was very different for Bolivia, Ecuador, Paraguay and Haiti, which made up the group of nations with such a limited degree of electrical development that they brought up the rear, very much behind the other Latin American nations.

When we take stock of the national achievements in electrical development, it is not sufficient to merely consider the results shown in this section, much as they may have shed light on something whose real dimension was unknown until now: the great diversity in the heart of Latin America and the strong expansion of electrical equipment which occurred in most countries between the end of the nineteenth century and 1930. However, it is not possible to judge this expansion in a balanced way without comparing the levels reached in Latin America with those recorded for other nations. The contrast should be made in terms of the electricity production per inhabitant – which, as

well as constituting the basic measure of the degree of electrical development, is the only variable with enough information for the period around 1930.[87] Figure 2 shows the results of the comparison with a wide selection of countries, both developed and underdeveloped.

<figure 2>

The achievements of Latin America now seem relatively modest, when considered in view of the position occupied by most Western countries. Latin American electrical production (65kWh per inhabitant[88]) at this time represented only 11 percent of the production of 17 Western countries. All of the Latin American countries were far from this level. It is true that this figure reflects record highs of countries that were extremely well-endowed with hydro-electric resources (Norway, Canada, and Switzerland) or countries whose development was exceptional (the United States). On the other hand, it is striking that the most advanced Latin American countries (Cuba, Chile, and Argentina) were located above the European economies of late industrialisation, such as Spain, Portugal, Greece, Hungary or Romania. Even the most backward economies in Latin America, excepting Haiti and Paraguay, had a higher level of electrical development than the Asian nations (excluding Japan), and most definitely than Africa (not reflected in the figure due to uncertainty about its population size). In short, the balance of the process of electrification of Latin America leads us to a conclusion which is partly optimistic and partly pessimistic. Optimistic in the sense that Latin America can be said to occupy the position of the Second World, behind the developed economies but ahead of the Third World ones (Asia and Africa). Nevertheless, on the other hand, this data does not encourage an optimistic reading. The level of electrical development reached by Latin America in 1930 was that which the United States had reached in 1901, Sweden in 1908, Germany in 1909, the United Kingdom in 1914, Italy in 1915, and France in 1917. In other words, Rippy was not right, but he was not completely on the wrong track. The gap between Latin America and the pioneer countries was greater at the end of the electric revolution than at the beginning.

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[87] As I have pointed out, this is not the case of Latin America. In the many cases in which production is unknown, I have estimated it working from total load capacity in 1930 (see table 1), applying a load factor of 25 percent. This factor (2,190 hours annually) seems reasonable because it is the average of the known national cases and coincides approximately with other indexes, although, of course, the margins of error are not reduced.

[88] ECLAC, *La energía en América Latina*, p. 27, calculates a consumption per inhabitant of 72 kWh in 1929. I think their estimation is riskier than mine for some countries that have very scant information. In any event, even if we accepted the validity of the figure proposed by ECLAC, the comparison with the most advanced countries leads to the same conclusions.

IV

Latin America participated punctually in the advent of the era of electricity –at least, the most advanced nations of the region did, as well as others which were not advanced. In the 1880s electric lighting was introduced in the main cities, generally an initiative of local business people. In the mining areas, electric engines soon appeared for use in the pumping of water, the transport and crushing of minerals and for other functions. Often, it was the mining companies themselves which supplied the neighbouring towns with electric current. Some years later, at the turn of the century, electric trams started to circulate in the most dynamic cities, almost at the same time as they did in Europe. In the new century, industries now began to equip themselves with electricity not to illuminate their installations but rather to move machinery. The manufacturing industry of the most developed economies (Argentina, Chile, and Uruguay), or those countries with strong industrial areas (Brazil), followed in the wake of their counterparts of the United States and Europe in the transition from steam powered technology to the electric motor. Some areas –in Brazil, Mexico and Chile– which were well-endowed with basic metallic minerals (iron and copper) powered a metallurgical industry based on electrolysis.

However, the consumption of electricity per inhabitant remained low half a century after the beginning of electrification, when the electric revolution could be said to have run its course. Only Cuba, Chile, Argentina, Costa Rica, Mexico and Uruguay, in this order, had reached consumption levels comparable to those of late industrialised European economies. The rest, except for Brazil and Peru, made extremely limited use of electricity, scarcely more than in the Asian countries (excepting Japan).

Electric underdevelopment was closely linked to economic underdevelopment. The main cause for the limited consumption of electricity was the low demand. In prosperous Cuba, heading the Latin American ranking of electric consumption, the capital city had electrical infrastructure comparable to that of North American cities. However, in many towns in the interior, there were numerous homes with electrical appliances limited to a single lamp illuminating the interior.[89] As one can imagine, in the poorest countries, like Bolivia, such a state of electrical poverty was very widespread.[90]

Such a limited demand severely conditioned production. Outside the big cities, the supply of electricity was organised in a very inefficient manner. This, in turn, became a major obstacle for a greater use of electricity. In other words, Latin America suffered from a typical vicious circle, condemning it to not be able to break out of the backwardness, caught between weak demand which impeded the appearance of offerors capable of achieving high productivity and

[89] Smith, *Electrical goods in Cuba*, pp. 19 and 22.
[90] Smith, *Electrical goods in Bolivia*, p. 12.

producers which, by offering a limited service that was expensive and of low quality, inhibited demand. The institutional framework itself led to the formation of a totally fragmented electrical market, which was exclusively municipal. The insufficient size of the market imposed an electrical system model that was inefficient.

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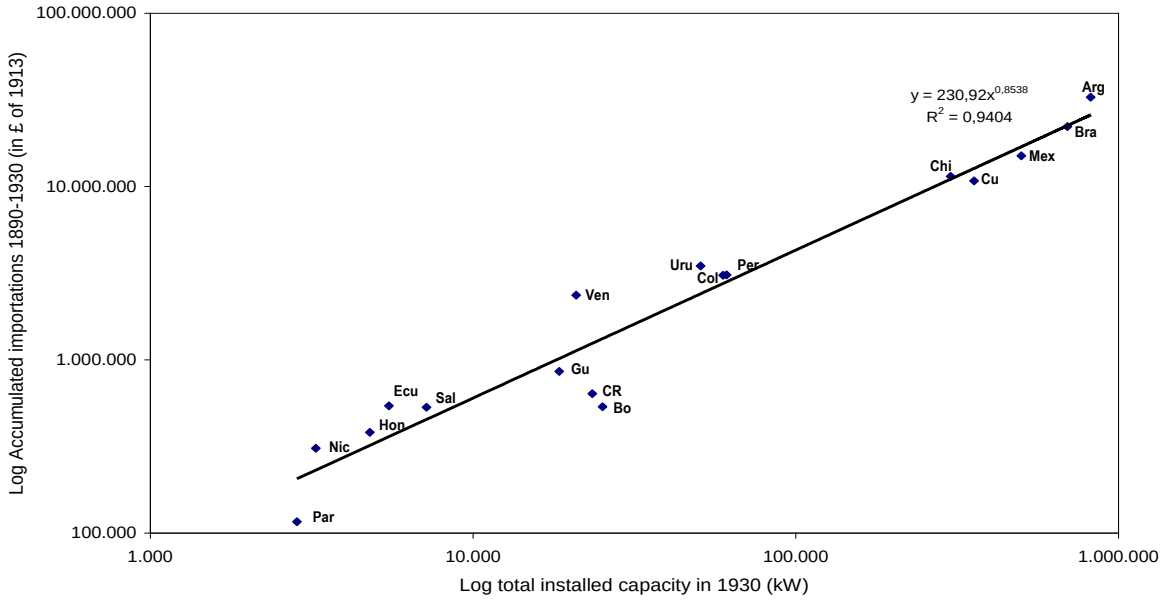
Figure 1

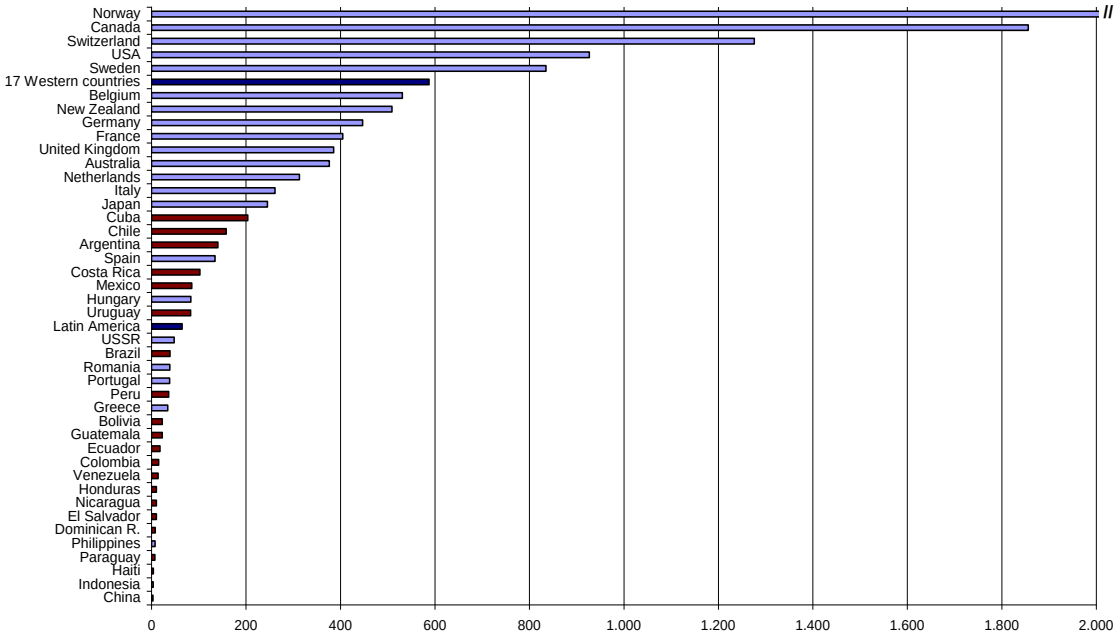
Figure 1. ***Importations of electric equipment and electric generation capacity***



Sources Table 1 and 2

Figure 2

Figure 2. ***Electricity production per inhabitant in 1930 (kWh)***



Sources: Mitchell, *International historical statistics: Africa*; *International historical statistics: Europe*; *International historical statistics: the Americas*; and, for Latin America table 1. The population figures come from Maddison, *Statistics on world*.

Table 1. *Total installed capacity in 1930, in kW*[*]

Argentina[a]	820,241
Bolivia[b]	25,200
Brazil[c]	694,872
Colombia[d]	59,564
Costa Rica[e]	23,424
Cuba[f]	357,147
Chile[g]	302,000
Ecuador[h]	5,491
El Salvador[i]	7,174
Guatemala	18,500
Haiti	—
Honduras	4,791
Mexico[j]	500,000
Nicaragua	3,261
Panama (including Canal Zone)	6,931
Paraguay[k]	2,850
Peru[l]	61,097
Dominican Republic	—
Uruguay	50,721
Venezuela[m]	20,888
Latin America	2,964,151

[*]Unless stated otherwise, information comes from Bradley, *Fuel and power*.

[(a)]I have taken as valid the figure offered by Bradley, *Fuel and power*, for 1926. The figure corresponding to 1930 was estimated by projecting the growth rate of the period 1916-27, which is only slighly higher than that of 1927-35.

[(b)] CIER, *25 años*, p. 148).

[(c)] Brazil. Ministerio da Agricultura, *Utilisação de energia electrica*, p. 343.

[(d)] I have followed the same procedure as for Argentina.

[(e)] I have considered that the figure Bradley, *Fuel and power*, offers as hydroelectric capacity (31,400 H.P.) really corresponds to that of total capacity, since according to other sources the former was 18,000 kW.

[(f)] I have estimated the power of the public power plants at 179 MW, based on the information according to the Statistical Yearbook of Cuba (1952, p. 127), that the capacity of plants in the censuses (170 MW) covered more than 90% del total (I have supposed 95%). The 162 MW correspond to the capacity of the sugar plants of 1927, according to Altshuler, 'Impacto social'. I have supposed that their capacity did not increment until 1930. I have added arbitrarily 10% for the rest of the autonomous producers.

[(g)] CIER, *25 años*, p. 223.

[(h)] According to Brandley, *Fuel and power*, p. 104, the hydroelectric capacity was 6,400 H.P. at the end of 1930. I have added 15% more, following his judement that only a small portion of the electric energy was of thermal origin.

[(i)] This information is the result of accepting for 1927 the information of the U.S. Department of Commerce, *Central lights and power plants*, and extrapolating the growth rate for the period 1916-27, according to Bradley, *Fuel and power*, p. 72.

[(j)] Mexico. Dirección Nacional de Irrigación, *La industria eléctrico en México*, pp. 23-4.

[(k)] Brandley, *Fuel and power*, allocates 2,700 kW of thermal power (to wood), to which I have added a small hydroelectric plant which, according to this author, existed and whose capacity I have supposed was 200 H.P.

[(l)] I have extrapolated to 1930 the growth rate of the installed capacity between 1934 and 1940. Both these pieces of information come from ECLAC, *La energía eléctrica en América Latina*. The result is consistent with the figure of hydroelectric power installed in 1930, according to Brandley, *Fuel and power*, (55,000 H.P.), if we suppose that at that date there was the same proportion between hydro and thermal as in 1940, according to the Statistical Yearbook of Peru from 1945.

[(m)] This refers to 1929.

Table 2. *Importations of electric equipment goods from the Germany, United States and United Kingdom (G-3), in pounds sterling of 1913*

years	Argentina	Bolivia	Brazil	Chile	Colombia	Costa Rica	Cuba	Ecuador	El Salvador	Guatemala	Haiti	Honduras	Mexico	Nicaragua	Paraguay	Peru	Dominican Republic	Uruguay	Venezuela	Latin America[a]
1891	14,719	2	293,030	20,636	11,848	2,836	32,624	2,091	7,701	12,043	2,717	1,396	60,241	2,260	688	15,421	345	10,392	11,069	**502,057**
1892	44,297	0	144,569	26,803	10,157	2,737	40,435	1,562	6,314	8,181	2,002	667	40,775	4,709	0	7,059	593	3,691	11,289	**355,840**
1893	20,582	0	44,484	46,184	9,226	2,244	36,240	1,527	3,479	6,360	1,449	401	30,946	826	0	4,726	1,184	3,760	11,330	**224,948**
1894	28,119	0	63,429	20,925	7,509	2,835	33,576	1,286	3,301	7,346	1,277	1,032	46,930	1,693	8	3,412	3,210	4,498	13,035	**243,419**
1895	44,252	0	343,096	19,108	7,798	4,453	25,021	1,545	4,369	12,733	1,429	1,626	67,943	3,923	100	7,272	3,766	5,625	16,861	**570,920**
1896	60,909	0	112,936	19,933	13,471	4,445	14,077	2,267	5,872	15,128	2,011	1,257	76,179	2,281	32	11,207	2,702	7,449	17,473	**369,628**
1897	80,098	0	123,186	15,609	14,480	3,551	8,386	2,225	5,446	14,363	872	1,870	120,327	2,739	23	9,446	1,971	5,618	18,564	**428,775**
1898	291,087	32	66,611	21,385	11,628	7,060	15,496	3,065	3,297	6,425	452	1,594	99,193	2,382	163	5,042	1,431	11,179	10,457	**557,979**
1899	198,941	131	95,152	76,393	8,764	8,682	38,459	5,634	2,792	4,399	524	1,045	111,812	2,174	859	13,375	2,582	12,718	5,208	**589,644**
1900	151,023	307	476,601	32,075	6,732	8,569	52,425	7,143	3,966	4,760	1,641	1,133	116,229	2,689	110	39,069	4,022	10,519	4,778	**923,791**
1901	131,066	2,332	81,566	19,681	5,943	5,425	43,598	3,876	2,988	4,332	1,452	1,071	83,763	1,529	828	14,192	2,776	9,708	6,131	**422,257**
1902	93,157	211	128,608	18,730	6,063	5,180	33,452	3,222	1,999	3,358	764	551	156,103	2,866	80	20,566	1,144	7,890	5,980	**489,925**
1903	119,171	621	109,736	36,810	7,607	12,049	33,362	4,807	2,519	2,721	1,298	930	146,581	3,048	160	37,493	939	4,265	10,240	**534,357**
1904	141,678	699	166,242	43,797	7,050	11,477	94,758	5,109	2,992	3,772	837	1,779	147,181	1,614	762	32,733	1,539	6,930	18,743	**693,688**
1905	279,722	1,269	205,451	241,588	13,274	5,698	126,334	5,660	4,895	5,377	1,103	2,101	244,340	2,580	253	43,325	2,796	17,054	21,617	**1,234,727**
1906	694,142	5,426	368,583	173,199	8,027	10,104	133,813	6,602	5,203	5,721	609	2,337	309,181	2,831	2,379	69,596	3,007	87,927	30,204	**1,939,063**
1907	796,253	9,645	452,683	205,123	15,571	12,631	157,754	8,366	6,478	9,907	590	1,639	334,181	2,151	782	94,708	2,577	260,308	37,643	**2,438,264**
1908	704,662	3,321	420,479	370,699	11,115	10,657	131,575	6,612	4,981	5,777	408	1,088	251,164	1,322	442	38,820	2,331	113,525	20,929	**2,140,674**
1909	828,465	9,220	638,462	164,823	20,253	18,300	142,800	7,446	7,458	8,020	1,909	2,479	453,516	2,498	42	47,906	3,755	82,497	20,544	**2,532,774**
1910	1,312,463	9,531	1,141,568	257,972	32,850	20,736	247,152	8,045	11,588	8,642	7,974	5,400	744,494	4,850	2,741	50,128	5,776	208,467	28,268	**4,194,347**
1911	1,076,044	9,764	1,088,696	254,517	29,610	15,832	224,650	7,331	10,097	7,964	6,883	8,205	542,715	6,346	633	42,634	7,637	117,769	29,221	**3,540,953**
1912	1,264,658	16,053	1,225,086	382,087	39,462	22,325	274,749	10,754	12,236	13,552	3,177	7,816	503,511	4,715	19,751	65,641	23,746	153,286	26,612	**4,244,366**
1913	1,444,324	23,813	1,153,563	417,299	58,672	26,616	293,945	13,655	13,739	16,936	4,192	6,804	439,035	7,114	19,273	96,020	28,142	122,109	38,081	**4,504,234**
1914	897,661	12,871	564,947	224,407	61,856	24,963	260,460	21,532	10,780	10,811	2,555	11,379	234,520	6,959	662	61,950	14,015	67,613	34,395	**2,743,944**
1915	301,968	8,599	258,182	107,222	47,169	16,953	291,596	18,736	10,909	6,338	1,487	11,703	128,198	4,520	228	50,064	7,415	55,698	38,378	**1,512,071**
1916	287,102	6,019	363,899	225,775	49,864	12,205	413,126	14,978	13,076	8,781	4,066	10,173	164,139	5,031	459	57,616	10,525	39,771	43,358	**1,852,897**
1917	391,744	6,088	438,301	306,679	49,362	8,481	473,701	16,765	11,783	9,179	13,889	8,239	212,701	5,602	2,208	96,906	19,992	55,209	38,892	**2,300,562**
1918	320,859	11,941	322,237	337,703	31,460	3,720	352,060	10,179	6,390	5,515	13,002	4,074	206,674	4,758	2,999	77,217	19,239	45,435	24,337	**1,905,213**
1919	409,480	25,140	577,311	242,059	52,642	6,546	359,195	15,106	12,374	12,983	5,432	6,947	268,186	7,635	992	142,640	15,604	102,629	29,114	**2,337,288**
1920	770,924	17,999	851,546	256,656	109,226	16,660	899,228	24,759	20,895	19,281	10,209	13,764	490,284	18,811	3,689	290,184	39,036	104,537	54,998	**4,107,005**
1921	999,414	38,504	752,790	413,848	203,453	17,791	704,454	12,010	16,340	27,945	6,703	20,495	773,502	11,205	1,311	188,689	44,086	87,106	66,747	**4,476,654**
1922	814,222	12,028	396,619	462,235	58,512	10,097	248,420	20,108	9,805	15,460	4,014	17,586	419,727	5,628	548	70,649	24,260	80,062	44,947	**2,735,146**
1923	1,359,663	28,877	590,272	739,673	93,182	20,643	434,037	25,285	18,547	37,592	10,160	34,108	469,737	11,586	675	137,297	23,202	127,524	54,628	**4,259,385**
1924	1,133,903	26,512	810,949	492,375	114,658	32,275	668,883	24,200	26,773	72,965	9,468	20,741	913,882	20,672	2,220	156,455	27,231	90,660	80,111	**4,787,166**
1925	1,441,064	23,220	910,637	452,587	134,160	27,778	722,756	27,588	37,123	46,299	10,396	19,555	723,027	18,575	2,796	153,913	27,539	139,972	111,581	**5,143,559**
1926	2,116,949	28,892	1,007,028	1,057,521	216,567	26,236	521,975	42,279	41,920	86,745	18,993	24,937	775,973	16,949	2,415	138,017	25,247	145,606	199,879	**6,582,963**
1927	2,386,554	27,041	1,147,507	606,436	329,093	28,778	546,082	34,198	40,064	79,902	16,947	30,673	881,460	15,973	4,125	186,170	50,479	183,634	217,439	**6,906,678**
1928	3,041,710	44,745	1,335,760	674,193	437,658	61,436	486,837	36,895	40,416	92,432	15,977	29,006	894,733	27,700	18,689	140,311	60,096	188,472	236,498	**7,977,386**
1929	2,963,621	58,250	1,681,089	810,677	423,760	62,207	588,479	38,733	46,080	84,638	21,218	25,889	996,050	29,105	9,225	204,984	39,494	239,791	266,558	**8,714,470**
1930	3,272,706	66,291	1,198,184	1,146,426	306,531	35,572	562,654	39,026	34,710	50,745	20,019	37,894	1,343,882	28,413	12,756	163,728	50,414	458,057	403,632	**9,453,167**

[a] Including Panama

Sources:

Derived from the sources cited in Tafunell and Carreras, 'La América Latina y el Caribe'. The current values in dollars and marks have been converted into pounds sterling applying the exchange rates related by Carter, *Historical statistics*, vol. 5, pp. 565-7, series Ee617, p. 5-565, for pound sterling exchange rate before 1914; series Ee636, p. 5-569, for pound sterling exchange rate since 1914; series Ee626, p. 5-567 for mark exchange rates, except for 1918. The source for this year is U.S. Department of

Commerce, *Foreign commerce yearbook 1925*, 2, p. 276 (Washington, 1926). Once all the values have been denominated in pounds, they have been converted into constant values using as a deflator the implicit unit value of the exportations of electric material of Switzerland. Direction Générale des Douanes Fédérales, *Statistique du commerce de la Suisse avec l'étranger* during the period 1906-30. For the 1891-1906 period the series were deflated with the price index of the investment in general plant and machinery in of the United Kingdom; see Feinstein, 'National statistics', table XXIII, pp. 470-1.

Table 3. *Annual growth rates of importations of electric equipment*

years	Argentina	Bolivia	Brazil	Chile	Colombia	Costa Rica	Cuba	Ecuador	El Salvador	Guatemala	Haiti	Honduras	Mexico	Nicaragua	Paraguay	Peru	Dominican Republic	Uruguay	Venezuela	Latin America
1891-1929	15.0	30.4	4.7	10.1	9.9	8.5	7.9	8.0	4.8	5.3	5.6	8.0	7.7	7.0	7.1	7.0	13.3	8.6	8.7	7.8
1891-1913	23.2	51.9	6.4	14.6	7.5	10.7	10.5	8.9	2.7	1.6	2.0	7.5	9.4	5.4	16.4	8.7	22.2	11.9	5.8	10.5
1913-1929	4.6	5.8	2.4	4.2	13.2	5.4	4.4	6.7	7.9	10.6	10.7	8.7	5.3	9.2	-4.5	4.9	2.1	4.3	12.9	4.2
1891-1900	29.5	71.5	5.6	5.0	-6.1	13.1	5.4	14.6	-7.1	-9.8	-5.4	-2.3	7.6	1.9	-18.4	10.9	31.4	0.1	-8.9	7.0
1901-1913	22.1	21.4	24.7	29.0	21.0	14.2	17.2	11.1	13.6	12.0	9.2	16.7	14.8	13.7	30.0	17.3	21.3	23.5	16.4	21.8
1913-1920	-8.6	-3.9	-4.2	-6.7	9.3	-6.5	17.3	8.9	6.2	1.9	13.6	10.6	1.6	14.9	-21.0	17.1	4.8	-2.2	5.4	-1.3
1921-1929	14.6	5.3	10.6	8.8	9.6	16.9	-2.2	15.8	13.8	14.9	15.5	3.0	3.2	12.7	27.6	1.0	-1.4	13.5	18.9	8.7

Source: see table 2.

Table 4

Levels of importations of electric equipment per inhabitant, in relation to the Latin American average (Latin America = 100)

	1891-9	1928-30	1891-1930
Argentina	269	312	285
Cuba	218	170	285
Chile	139	244	233
Uruguay	118	205	201
Costa Rica	213	127	120
Mexico	75	75	74
Brazil	120	50	67
Venezuela	71	108	59
Peru	34	37	51
The Dominican Republic	56	48	50
Guatemala	97	51	40
Nicaragua	79	49	38
Honduras	37	39	38
Colombia	36	59	35
El Salvador	80	34	35
Ecuador	23	23	23
Bolivia	0	28	19
Paraguay	7	19	13
Haiti	13	9	8

Sources:

Table 2 and the population series come from Maddison, *Statistics on world*. In the cases where Maddison does not provide annual statistics for 1891-9, the population statistics for 1890 come from Bulmer-Thomas, *Economic history of Latin America*, p. 412. The values for the remaining years have been estimated by means of exponential interpolation.