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Telephones and Economic Growth: A Worldwide Long-Term Comparison with Emphasis on Latin America and Asia

JOSÉ LUIS CORDEIRO

日本貿易振興機構 アジア経済研究所

INSTITUTE OF DEVELOPING ECONOMIES, JAPAN EXTERNAL TRADE ORGANIZATION

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SUMMARY

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José Luis Cordeiro *

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This study gives a global summary of the evolution of telephones and economic growth around the world, with a particular focus on comparisons between Latin America and Asia. A total of 41 countries have been included: 9 in Latin America, 11 in Asia, 2 in North America, 2 in Oceania, 2 in Africa and 15 in Europe. The time period considered is the complete 20th century, beginning in 1900, even if earlier data has also been used for countries where such information was available.

The telephone allowed the immediate and simultaneous interconnection of many people around the world, for the first time in human history. This produced obvious benefits, many of which can be seen in the unprecedented rates of growth experienced last century. Therefore, the 20th century could be called the "Age of the Telephone".

The telephone statistics used here correspond to the adjusted historical number of fixed telephone lines, and economic growth was measured in terms of GDP. All figures were converted to per capita terms. The analysis shows that there is very high correlation between telephones and economic growth, and also high convergence (both $\beta$and σ convergence) among most countries and regions of the world. There are also some positive results in terms of the causality relation from telephones to GDP, but a more common pattern seems to be the causality from GDP to telephones. However, there is no general pattern of causality among all countries or regions.

Finally, some implications of this new and increasing interconnected world are considered. New mobile telephones in the 21st century are substituting the old fixed landline telephones of the 20th century, bringing cheaper, faster, better and more efficient ways to communicate in our now interconnected world.

* Visiting Research Fellow (VRF), Institute of Developing Economies, IDE-JETRO
Invited Professor, Universidad Central de Venezuela
Academic Committee, CEDICE, Venezuela
Chair, Venezuela, The Millennium Project
Email: jose@cordeiro.org

CHAPTER 1: A Long-Term View of Development

In recorded history there have been perhaps three pulses of change powerful enough to alter man in basic ways: the introduction of agriculture... the Industrial Revolution... and the revolution in information processing…

Herbert A. Simon, Nobel Prize in Economics, 1978

1.1. Interdisciplinary Background

The term "economic development" came into use after World War II. The urgent need at the time was the economic development of Europe, particularly the industrialization of Eastern Europe, where methods of central planning were first experimented. Soon afterwards, the attention of many economists turned towards Asia, Africa and Latin America. However, the conditions of the developing world were, and still are, very different from the situation of post-WWII Europe.

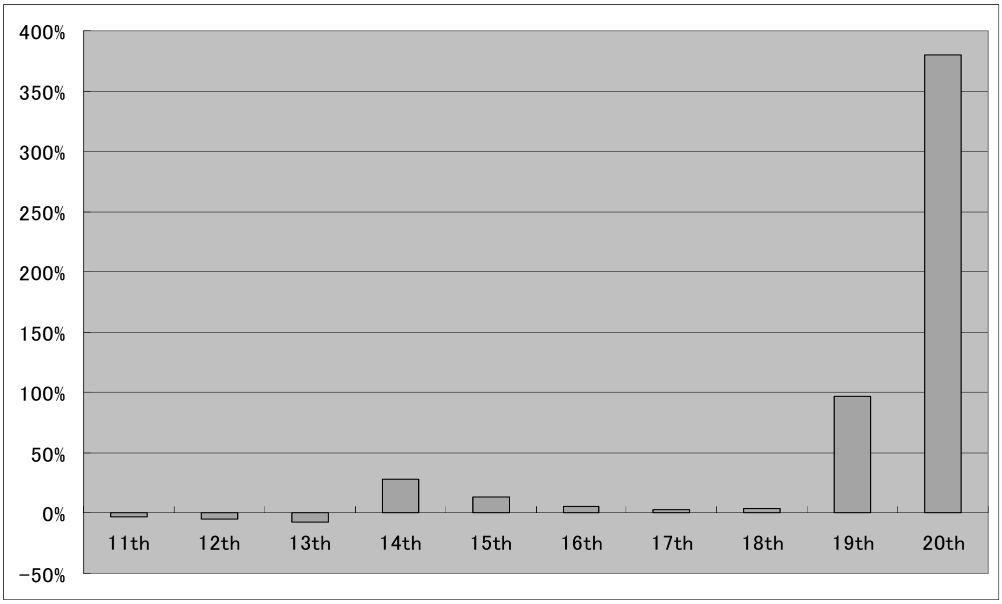
Economic history brings a long term perspective to the issues of economic development, including different periods of time with relative convergence and divergence across many world regions. The English economic historian Angus Maddison (2007) has published extensively about economic growth in the last few centuries, with a quantitative approach that he has tried to extend all the way back two millennia, and even now making some forecasts two decades into the future. Some historians and macrohistorians have also done long-term analyses focusing on the development and evolution of major world civilizations (e.g., Paul Kennedy [1987]).

An even newer and more interdisciplinary perspective has incorporated the ideas of biologists and other scientists into the evolutionary development of humanity. Matt Ridley (1996), Jared Diamond (1997) and Klaus Jaffe (2007), for example, have considered the evolutionary history of life on Earth and how it impacts the way in which humans interact in different contexts today. The views of economists, historians, biologists and other social and natural scientists are enriching our knowledge of the complex development process under an interdisciplinary context.

The acceleration of economic growth, as measured by GDP (Gross Domestic Product) reconstructions, is staggering. For the most part of recorded human history (normally defined after the invention of writing), and certainly much longer before then, humans lived in near subsistence conditions. The English philosopher Thomas Hobbes, clearly characterized this in his 1651 book, *Leviathan*,[1] writing that life in the state of nature was "solitary, poor, nasty, brutish, and short."

Since 1651, many things have obviously changed, the economic conditions for the majority of the people have increased, compared to the long-term historical record, and economic growth has accelerated. According to Maddison (2007), during the first millennium, the income per capita actually went down from 467 to 453 (measured in 1990 International Geary-Khamis dollars) between the year 1 AD and the year 1000 AD. During the second millennium, growth was also very slow at the beginning (even negative again) but it accelerated in the 19th century, followed by an impressive growth in the 20th century, as shown in Figure 1-1. The unprecedented growth during the 20th century might even be surpassed during the 21st century thanks to the recent impressive growth on China, India, and many other countries, some following the "Flying Geese Paradigm" championed by Japan.[2]

Figure 1-1: GDP Growth by Century during the Second Millennium (% Change)



Source: Cordeiro based on DeLong (2000) and Maddison (2007)

[1] The book *Leviathan* was titled after the biblical Leviathan, and its complete name was *Leviathan, or The Matter, Forme and Power of a Common Wealth Ecclesiasticall and Civil*. The book argued about a social contract, under an absolute sovereign, in order to avoid the disasters during the English Civil War (1642-1651).

[2] The "Flying Geese Paradigm" is a development view popularized by some Japanese scholars emphasizing the technological development in parts of Asia following Japan as a leading power.

1.2. The Agricultural Revolution

The first radical historical change in the living conditions of humans was the invention of agriculture. About 10.000 years before the present, the transition from nomadic hunting and gathering communities to agriculture and settlement in small urban centers. It occurred independently in various separate prehistoric human societies based on different staples, like wheat in the Middle East, corn in Latin America, rice in Asia, for example. The agricultural transition coincided with the adoption of early farming techniques, crop cultivation, and the domestication of animals.

The Australian philologist and archaeologist Vere Gordon Childe is credited with coining the terms "Neolithic Revolution" and "Urban Revolution" in order to describe this "Agricultural Revolution" starting in the Neolithic Age (or New Stone Age, from Greek). He made his first excavations in Scotland and attempted to place his discoveries into a general theory of prehistoric development on a wider European and world scale (1925).

The Agricultural Revolution is also notable for developments in social organization and technology. Among the major changes often associated with the introduction of agriculture are an increased tendency to live in permanent or semi-permanent settlements, a corresponding reduction in nomadic lifestyles, the concept of land ownership, modifications to the natural environment, the ability to sustain higher population densities, an increased reliance on vegetable and cereal foods in the total diet, a less egalitarian society and the birth of "trading economies" using surplus production from the increasing crop yields. Many new technologies were also developed, mostly related originally to agriculture, from irrigation channels to crop rotations. The relationship of these changes to the start of agriculture, to each other, their sequence and even whether some of these changes are supported by the available evidence remains the subject of much academic debate, and varies from place to place as well.

The issues and consequences of the Agricultural Revolution are still sometimes hotly debated, and Jared Diamond called it "the worst mistake in the history of the human race":

> *Hunter-gatherers practiced the most successful and longest-lasting life style in human history. In contrast, we're still struggling with the mess into which agriculture has tumbled us, and it's unclear whether we can solve it.* [3]

Mistake or no mistake, agriculture is a fact of history, just like the increasing growth of human population and the expansion of trading economies that allowed the division of labor afterwards.

[3] Diamond, J.M. (1987). The Worst Mistake in the History of the Human Race. Discover Magazine, May 1987, pp. 64-66.

1.3. The Industrial Revolution

The term "Industrial Revolution" was usually applied to technological change in the 1830s. The French political activist Louis-Auguste Blanqui spoke of *la révolution industrielle* as early as 1837, and the German philosopher Friedrich Engels spoke of "an industrial revolution, a revolution which at the same time changed the whole of civil society" in *The Condition of the Working Class in England in 1844*. However, the major credit for popularizing the term may be given to the English economic historian Arnold Toynbee, whose lectures in the 1880s gave a detailed account of the process.

The Industrial Revolution was a period in the late 18th and early 19th centuries when major changes in several industries (including mechanized agriculture, manufacturing and transportation) had a profound effect on the socioeconomic and cultural conditions first in England, and later in other countries. The causes of the Industrial Revolution are complicated and remain a topic for debate, but some historians believe that the Revolution was as an outgrowth of social and institutional changes brought by the end of feudalism in England after the English Civil War in the 17th century.

Many historians still debate why the industrial revolution started in Europe and not in other parts of the world, particularly China, India, and the Middle East, which had comparable development levels at the time. Historians also debate why it happened in the 18th century and not at earlier times like in Classical Greece or Rome, the Arab Caliphates, the Middle Ages, the Italian Renaissance or Ming China. Numerous factors have been suggested, including climate, culture, demography, ecology, ethnicity, food, geography, government, and even religion.

Just like with the Agricultural Revolution, the fact is that the Industrial Revolution happened, for better or for worse, and it has been expanding around the world since then. There has been opposition many times, and in many places, like the Luddite social movement of English textile artisans in the early 19th century. The Luddites were against the changes produced by the Industrial Revolution, which they felt threatened their livelihood, and protested and destroyed the new mechanized looms.[4]

Many authors consider that the Industrial Revolution can been divided in clearly identifiable parts. For example, the First Industrial Revolution from 1760 to 1830 followed by the Second Industrial Revolution after 1850 (e.g., David Landes [1969]). The First Industrial Revolution started with the mechanization of the textile industries, the development of iron-making techniques and the increased use of refined coal. Trade

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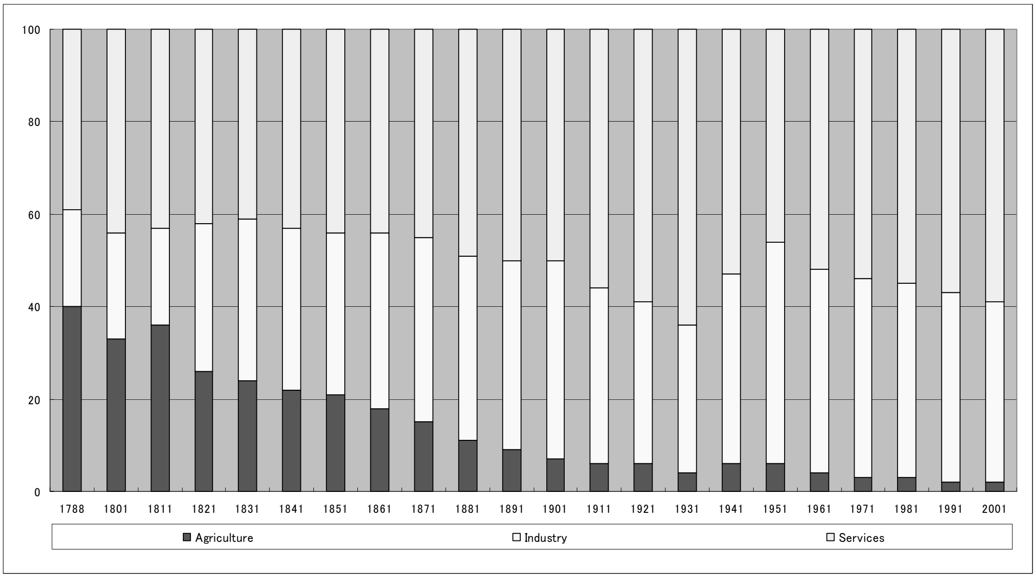
[4] The Luddite movement began in 1811 and took its name from the earlier Ned Ludd. The movement became briefly so strong that it clashed in battles with the British Army, and some of its members were sentenced to death. Since then, the term Luddite has been used to describe anyone opposed to technological progress and technological change.

expansion was enabled by the introduction of canals, improved roads and railways. The introduction of steam power (fuelled primarily by coal) and powered machinery (mainly in textile manufacturing) created the dramatic increases in production capacity. During the Second Industrial Revolution, the technological and economic progress gained momentum with the development of steam-powered ships, faster railways, and later the internal combustion engine and the electrical power generators. The worldwide growth of telecommunications in the early 20th century has led some historians to talk also about a Third Industrial Revolution.

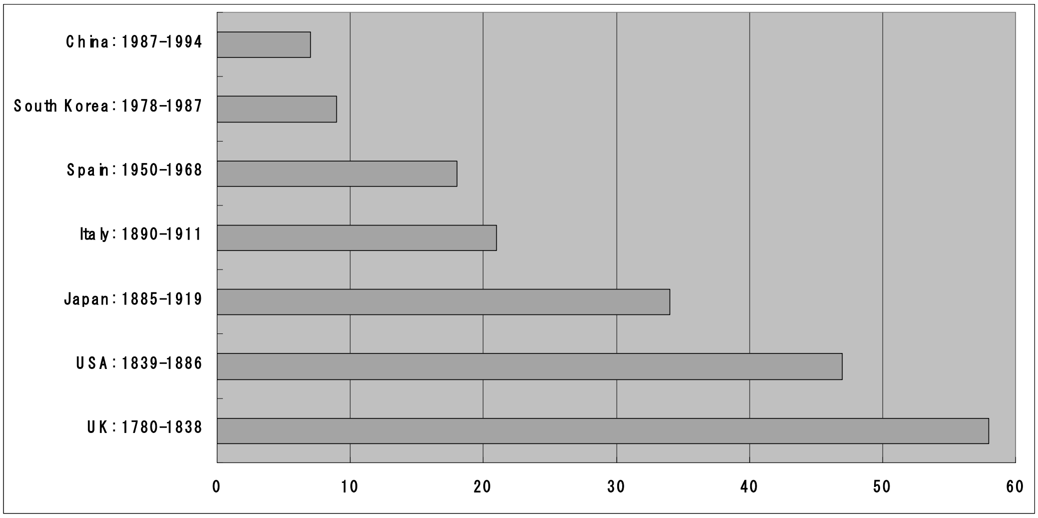
Before the Industrial Revolution, the majority of the people in most countries lived in rural communities and farms doing agricultural work. Until the middle of the 18th century, according to the available statistics, agriculture was the main economic activity in England, followed by services like commerce and trade. Slowly, the industrial sector began growing and the agricultural sector began shrinking, which was also due to the so-called British Agricultural Revolution that produced a massive increase in the agricultural productivity and net output. This allowed unprecedented population growth, freeing up a significant percentage of the workforce, and thereby helped drive the Industrial Revolution with new workers, many of whom were farmers before. The British Agricultural Revolution was driven by processes like the enclosure system (private closed farms), mechanization, advanced irrigation and drainage, four-field crop rotations, and selective breeding. Figure 1-2 shows the increase of the industrial sector and the decrease of the agricultural sector in Britain during the Industrial Revolution.

Figure 1-2: Evolution of GDP by Main Economic Sectors in the United Kingdom



Source: Cordeiro based on Mitchell (2008)

Figure 1-3: Acceleration of Growth: Years to Double Income for the First Time



Source: Cordeiro based on Maddison (2007)

Many trends that occurred in Britain were quickly followed by other European countries, and some former British colonies like the then newly independent United States of America, as well as Canada and Australia. Several learned societies (some modeled after the Royal Society of London) were established in different countries to promote scientific studies. The importance of intellectual property also grew and discoveries and innovations were protected by patents, licenses and other means. The *Encyclopædia Britannica* was first published in 1768, and since then it has been growing and improving to become the largest written encyclopedia in the world. Thanks to such developments in the Industrial Revolution, knowledge began to spread rapidly around the world. Improving telecommunications also allowed to know faster what was happening in other parts of the world. Thus, there has also been an acceleration in the rate of growth around the world, as shown in Figure 1-3.

The United Kingdom was the first country in the world to double its income per capita in a sustainable and systematic way during its Industrial Revolution, and it needed 58 years for that (from 1780 to 1838). Many other countries have followed since then, like the USA in 47 years (from 1839 to 1886), Japan in 34 years (from 1885 to 1919) and Italy in 21 years (from 1890 to 1991), for example. Currently, the world record in economic growth is China that has been doubling its income every 7 years.

1.4. The Information Revolution

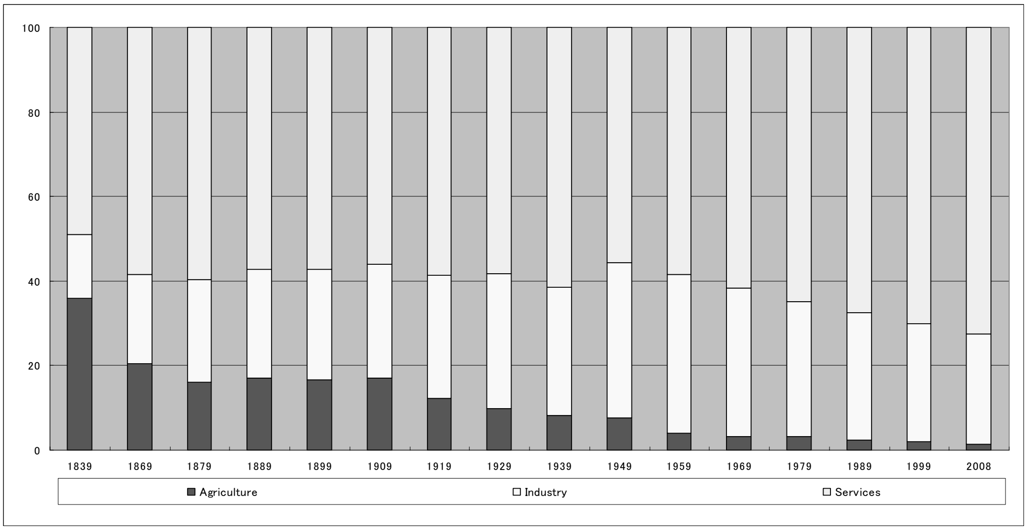
While the Agricultural Revolution took millennia to spread around the world, the Industrial Revolution needed less than a century to spread in many other countries, thanks also to the advances in knowledge and technology, particularly telecommunications. Now, with the new Information Revolution, the time needed is not millennia, nor even centuries, but decades and sometimes just years.

Since the second half of the 20th century, several authors have been writing about a new revolution. Not just a Third or Fourth Industrial Revolution, but something completely different. For lack of a widely recognized and better term, the "Information" (or sometimes Informational) Revolution is an appropriate classification for the current era.[5]

While the Agricultural Revolution started in the Fertile Crescent in the Middle East, and the Industrial Revolution began in England, this new Information Revolution originated in the USA during the 20th century. And it is spreading faster and farther than the previous two revolutions.

Figure 1-4 clearly shows the GDP evolution of the main economic sectors in the USA from the time since such statistics are officially kept. The decrease of the agricultural sector can easily be noticed, while the industrial and service sectors have grown. This trend is more striking for the employment evolution for the corresponding years, as shown in Figure 1-5. It is interesting to notice that over half of the US population was employed in the agricultural

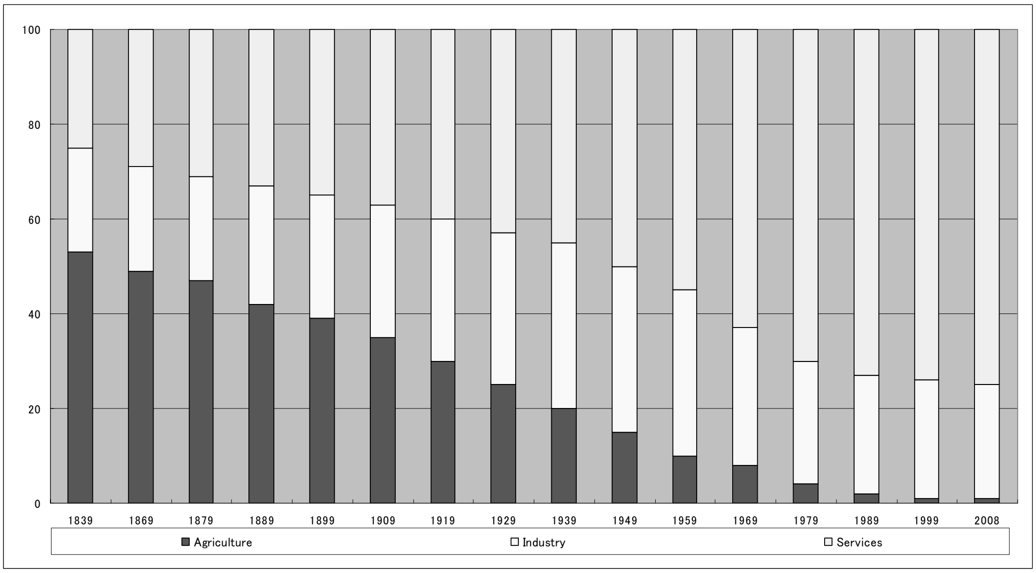
Figure 1-4: Evolution of GDP by Main Economic Sectors in the USA



Source: Cordeiro based on Mitchell (2008)

[5] Many names have been proposed by different authors. For example, Peter Drucker first wrote about the "Knowledge Economy" (1966), Daniel Bell about *The Coming of the Post-Industrial Society* (1973), Zbigniew Brzezinski proposed his Technetronic Society (1976), Alvin Toffler popularized *The Third Wave* (1980), Don Tapscott published *The Digital Economy* (1996), Shikhar Gosh studied the "Internet Economy" (1998), and Manuel Castells wrote about *The Rise of the Network Society, The Information Age* (1996).

Figure 1-5: Evolution of Employment by Main Economic Sectors in the USA



Source: Cordeiro based on Mitchell (2008)

sector at the beginning of the 19th century. Today, the US agricultural employment is less than 1% and that is enough not just to feed the US population but also to export many food products (since the USA is currently a net food exporter). Figure 1-5 shows the constant increase of the service sector, which is the main component of the economy during the Information Revolution.

This new Information Revolution is dependent on technology, particularly telecommunications, since the speed and spread of knowledge are fundamental to the creation of wealth today. In fact, the telecommunications sector basically did not exist two centuries ago, but today it represents about 3% of the global economy. And the telecommunications sector is growing consistently, even as the price of telecommunication services are falling dramatically, as will be seen in the next chapter.

CHAPTER 2: The Telecommunications Industry

Well-informed people know it is impossible to transmit the voice over wires. Even if it were, it would be of no practical value.

The Boston Post, 1865

Mr. Watson, come here, I want to see you.

Alexander Graham Bell "telephoning" his assistant Thomas Watson, March 10, 1876

2.1. The Beginnings

The word *télécommunication* was coined in 1904 by the French engineer Édouard Estaunié. It comes from the Greek prefix τηλέ (télé) "far" plus the Latin suffix *communicare* "to make contact". The original French word was soon adopted in English and most other languages. The word itself was spread quickly by the increasing speed and reliability of the telecommunication systems of the early 20th century.

Biologically speaking, one of the first forms of telecommunications was the evolution of languages that allowed advanced symbolic communications from one individual to another. Even though some animals have sophisticated communication systems, all the way from ants and bees to chimpanzees and dolphins, human language is an advanced symbolic communication tool that probably evolved with our first human ancestors at least 100,000 years ago. Certainly many animals also have different systems of communications, from audiovisual to olfactory mechanisms; however, only humans have perfected telecommunication systems based on technology.

In the prehistory of human civilization, there are examples of cave paintings with designs dating from about 30,000 BC in the Upper Paleolithic period. By definition, human history begins with the invention of writing systems, which can be traced back to the 4th millennium BC. (Even earlier, however, proto-writing, ideographic and mnemonic symbols emerged in the early Neolithic period, as early as the 7th millennium BC, if not earlier.) Writing itself emerged in a variety of different cultures in the Bronze Age, around 3,000 BC, mainly: Mesopotamian cuneiform scripts, Egyptian hieroglyphs and Chinese characters. Finally, during the Iron Age, around 1,000 BC, the first alphabets appeared: first the Phoenician alphabet (only consonants, not really an alphabet but an abjad), then the Greek alphabet (also with vowels), and later the Latin alphabet and many others. Documents were first written in stones, wood and shells, followed by papyrus in Egypt and then paper in China. The first postal system was developed in Egypt, where Pharaohs used couriers for the diffusion of their decrees in their territory since 2,400 BC. Persia, India, China and Rome also created their own postal systems since the first half of the 1st millennium BC.

In terms of audio signals, there is some evidence of drums and horns in parts of Africa before 3,000 BC. Similarly, for visual signals, there are remains of light beacons (fires) and possible smoke signals since 3,000 BC and earlier, in several parts of the world. The Greeks, and later the Romans, also perfected the heliographs for telecommunications since 490 BC, and heliographs could reach until 50 kilometers in good weather conditions.

The Chinese probably invented paper in the 2nd century BC, but it was only standardized by Cai Lun in about 100 AD. The first movable type printing press was developed by Pi Sheng in China around 1041 AD, and the first alphabetic movable type printing press was invented by Johannes Gutenberg in Germany around 1439 AD. Postal systems continued to evolve, including some times the use of homing pigeons (evidenced in Baghdad in 1150 AD) and many land and see transports.

In the late 18th century, the first telegraphs came in the form of optical telegraphs, including the use of smoke signals and beacons, which had existed since ancient times. A complete semaphore network was invented by Claude Chappe and operated in France from 1792 through 1846. It apparently helped Napoleon enough that it was widely imitated in Europe and the USA. The last commercial semaphore link ceased operation in Sweden in 1880.

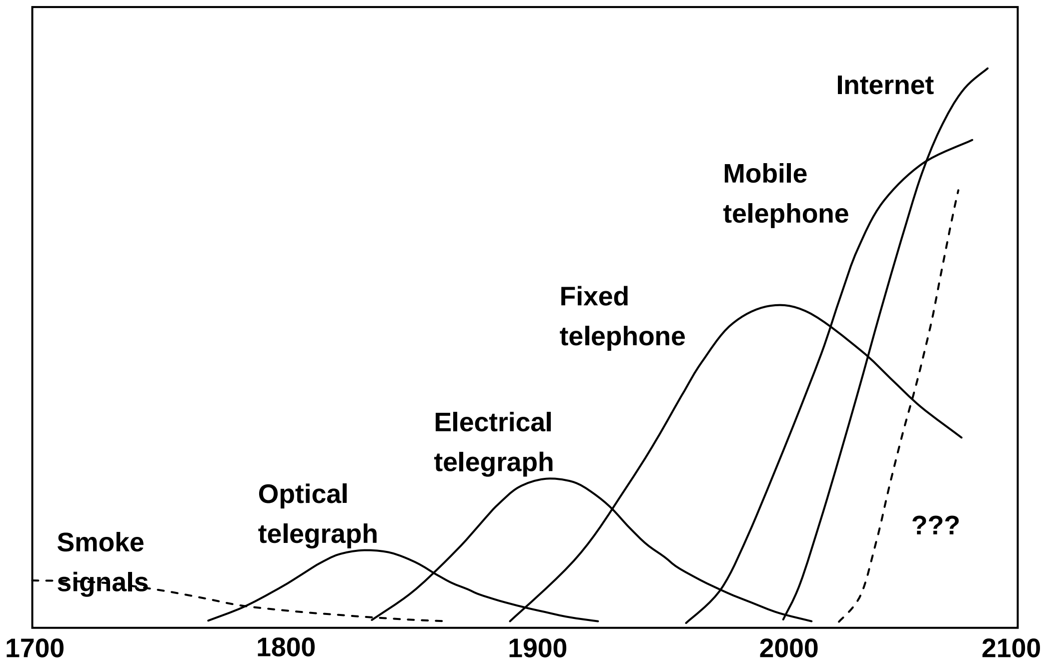
The first electrical telegraphs were developed in the 1830s in England and the USA. Sir William Fothergill Cooke patented it in May 1837 as an alarm system and it was first successfully demonstrated on July 25, 1837, between Euston and Camden Town in London. Independently in the USA, Samuel Morse developed an electrical telegraph in 1837, an alternative design that was capable of transmitting over long distances using poor quality wire. The Morse code alphabet commonly used on the device is also named after Morse, who developed it with his assistant Alfred Vail. On January 6, 1838, Morse first successfully tested the device in Morristown, New Jersey. In 1843, the US Congress funded an experimental telegraph line from Washington, DC, and Baltimore. The Morse telegraph was quickly deployed in the following two decades, and the first transcontinental telegraph system was established in 1861, followed by the first successful transatlantic telegraph cable in 1866.[6]

In only three decades, the telegraph network crossed the oceans to every continent, making instant global telecommunications possible for the first time in history. Its development allowed newspapers to cover significant world events in near real-time and revolutionized business, economics, science and technology. By now, however, most countries have totally discontinued telegraph services, like the Netherlands in 2004 and the

USA in 2006.[7] The invention of wireless telegraphy, as radio was originally called, also decreased the importance of electrical telegraphy in the 20th century. After over a century and a half, with an incredible high success, the electrical telephone has given way to more efficient and newer means of telecommunications, including the Internet.

Figure 2-1 shows the theoretical evolution of telecommunications in the last few centuries, from smoke signals to Internet, passing by optical telegraphs, electrical telegraphs, fixed telephone landlines and mobile telephones. It is worthwhile to note that each new system is on average faster, cheaper, more accurate and reliable, and also has a wider bandwidth than its predecessors. The changes in telecommunications are now very rapid and the efficiency of the systems is generally increasing.

Figure 2-1: Evolution of Telecommunications



Source: Cordeiro based on Huurdeman (2003)

[6] There had been earlier submarine transatlantic cables installed in 1857 and 1858, but they only operated for a few days or weeks before they failed.

[7] Some countries, like Japan, still use telegrams for special occasions like weddings, funerals, graduations, etc. Japanese local postal offices now offer telegrams printed on special decorated paper and envelopes.

2.2 The Invention of the Telephone

The first telephones, from the Greek words tele (τηλέ) "far" and phone (φωνή) "voice," arrived in the second half of the 19th century in the middle of claims and counterclaims of the individuals working on similar or related inventions.[8] As with other great inventions such as radio, telegraph, television, light bulb, and computer, there were several inventors who did pioneer experimental work on voice transmission over wires and improved on each other's ideas. Chronologically, Innocenzo Manzetti, Antonio Meucci, Johann Philipp Reis, Elisha Gray, Alexander Graham Bell, and Thomas Alva Edison, among others, have all been credited with pioneer work on the telephone.

The continued belligerence of the different and conflicting groups involved in the invention of the telephone delayed the quick development of a standard system during its very first years. However, the Bell and Edison patents were finally victorious and later proved themselves to be commercially profitable.

During the 1876 Philadelphia Exhibition, Bell received the unexpected and decisive support of Emperor Pedro II of Brazil, who was traveling in the USA at the time. Emperor Pedro II was curious about the telephone and recited into it Shakespeare's famous line from Hamlet –"To be or not to be"– and then exclaimed with surprise: "This thing speaks!" The Emperor was so impressed that he ordered the installation of a telephone in Brazil, which thus became the second country in the world to have telephones, after the USA.

In the high days of electrical telegraphy, Western Union was the unquestionable leader of telecommunications. When telephones were first invented in 1876, Western Union circulated an internal memo saying:

> *This "'telephone" has too many shortcomings to be seriously considered as a means of communication. The device is inherently of no value to us.*

When Alexander Graham Bell approached Western Union in order to sell his telephone patent for US$ 100,000, the committee charged with investigating the potential purchase wrote in a report to the President of Western Union:

> *Why would any person want to use this ungainly and impractical device when he can send a messenger to a local telegraph office and have a clear written message sent to any large city in the United States?"*

Against all odds, Bell continued with his patent and eventually founded, with the

[8] Brooks (1976) wrote a fascinating history of the telephone for its 100th anniversary, after its generally accepted invention in 1876: *Telephone: The First Hundred Years.*

help of financiers, the American Telephone & Telegraph Company in 1885.[9] He also bought a controlling interest in the Western Electric Company[10] from his rival Western Union, which only a few years earlier had turned down Bell's offer to sell it all rights to the telephone for US$ 100,000.

After the acquisition of Western Electric, AT&T expanded quickly and founded similar companies in many countries, for example, Canada, France, India and Japan. Thus, the former competitor Western Union remained the leader of the eventually shrinking telegraph industry, while AT&T became the leader of the growing telephone industry.

2.3 The Growth of an Industry

AT&T, together with its subsidiary Western Electric, oversaw an explosive growth of telephones during the late 19th century, first in the USA, later in Europe, and finally in the rest of the world. In just about two decades, the number of telephones passed the two million mark, over half of them in the USA, but with increasing numbers in Europe and other regions.

Table 2-1 shows the telephone growth during the end of the 19th century.
In the 1880s, AT&T began creating a national long distance network from New York City, which was eventually connected to Chicago in 1892. The AT&T national long distance

Table 2-1: Telephones Growth in the 19th Century

Year	USA	Europe	Rest of the World	Total
1880	47,900	1,900	-	49,800
1885	147,700	58,000	11,800	217,500
1890	227,000	177,000	31,500	435,500
1900	1,355,000	800,000	100,000	2,255,000

Source: Cordeiro based on Huurdeman (2003)

[9] The original Bell Telephone Company was founded in 1878 by Alexander Graham Bell's father-in-law, Gardiner Greene Hubbard, who also helped organized a sister company (the New England Telephone and Telegraph Company). The two companies merged in 1879 to form the National Bell Telephone Company, which in 1880 merged with others to form the American Bell Telephone Company, which in turn became the American Telephone & Telegraph Company (AT&T), SBC, and BellSouth, which would later merge to become the New AT&T.

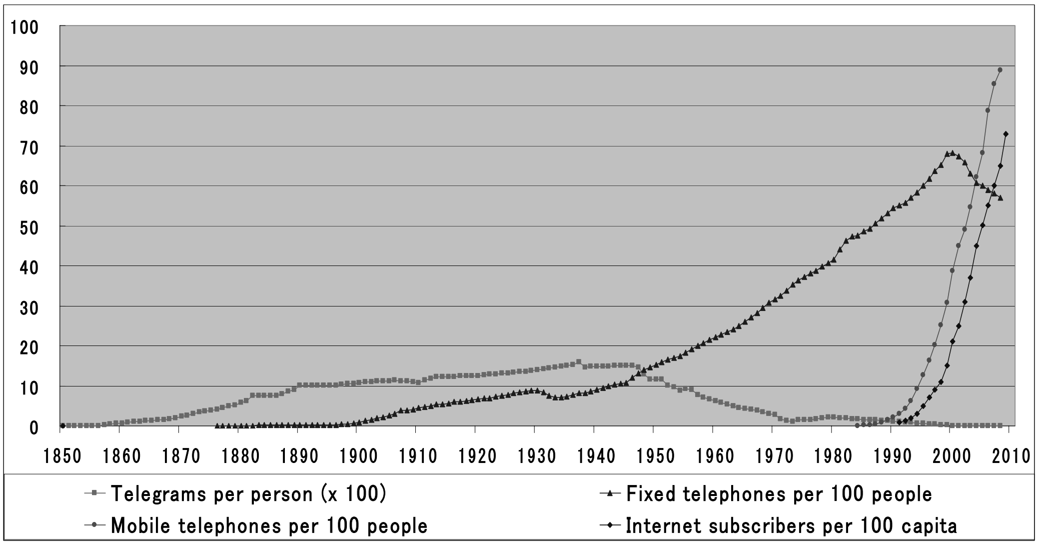
[10] Elisha Gray, another of inventors with telephone patents, bought shares of the Western Electric Company in 1869. In 1875, Gray sold his interests to Western Union, including the caveat that he had filed against Bell's patent application for the telephone. The ensuing legal battle over patent rights, between Western Union and the Bell Telephone Company, ended in 1879 with Western Union withdrawing from the telephone market and Bell acquiring Western Electric in 1881.

service finally reached San Francisco in 1915, thus connecting the East and West coasts of the USA. Transatlantic services started in 1927 using two-way radio, but the first trans-Atlantic telephone cable did not arrive until 1956, with the TAT-1 undersea cable between Canada and Scotland.

In the 1960s and 1970s, AT&T grew and grew, thus becoming a quasi national monopoly in the USA and some other countries where it operated. In 1982, "Ma Bell" was broken up in the USA and was split, following a famous antitrust suit against AT&T, into seven independent regional Bell operating companies known as "Baby Bells." Less than two decades later, with all the new technologies and more global competition, the natural monopoly status disappeared and SBC (one of the original Baby Bells, known by successive names as Southwestern Bell Corporation, later SBC Communications) reabsorbed some of the other Baby Bells plus the older but then much smaller AT&T Corp., and renamed itself as AT&T Inc. The new AT&T Inc., however, was not totally vertically integrated as the previous "Ma Bell".[11]

Figure 2-2 shows the evolution of telecommunications in the USA, with telegraphs dominated mostly by Western Union, fixed telephone landlines by the near monopoly of AT&T, and mobile telephones and Internet supplied by a larger variety of newer companies, both national and international.

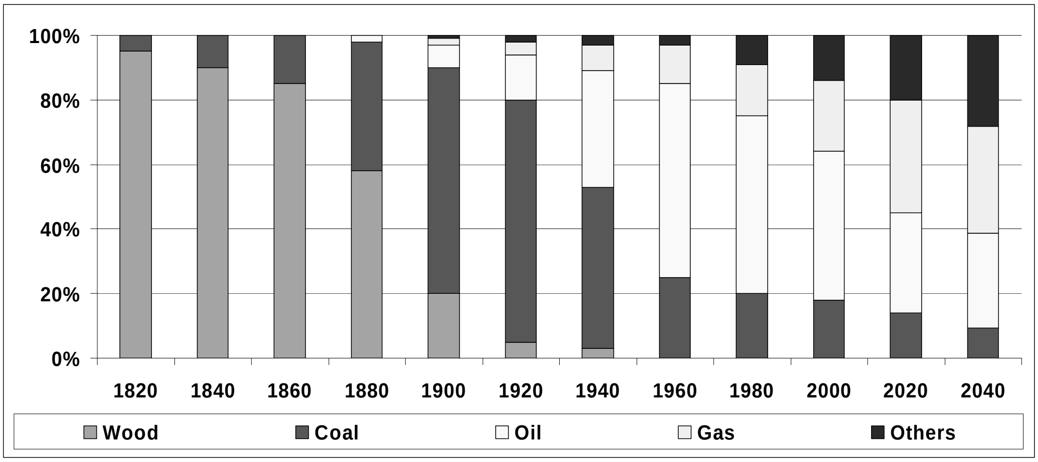
Figure 2-2: Evolution of Telecommunications in the USA



Source: Cordeiro based on Carter at al. (2006)

[11] For a detailed history of the US telephone industry, see Oslin (1992). For an international perspective, see Huurdeman (2003). For a brief chronology of telecommunications, see Appendix 1.

Figure 2-3: Evolution of Energy Sources in the USA (%)



Source: Cordeiro based on Glenn and Gordon (2006)

Similar technological "waves" can be seen in other industries, for example, in the energy sector. Figure 2-3 shows the evolution and forecasts of the energy sector in the USA from 1820 to 2040. Several waves or cycles can be clearly identified: first energy based on wood, second coal, third oil, fourth natural gas, and finally new energy sources. It is worthwhile to note that each subsequent cycle is faster and the waves become shorter with time. A similar conclusion could be reached about the telecommunications industry, with the new technologies having shorter and faster cycles.

Just as the 20^{th} century has been called the century of oil, the 20^{th} century will also be remembered as the century of the fixed telephone landlines. It is true that fixed telephone landlines have gone through major changes, but the general concept remained the same. The telegraphs before and the mobile telephones later are very different, but fixed telephones continue with the same basic model.

2.4 The Accelerated Reduction of Costs

Historic analogies seem to indicate that telecommunications will continue changing at faster rates. Additionally, the costs have been rapidly going down, particularly when an older technology is substituted by a newer technology. Table 2-2 shows the drastic fall in prices after the electrical telegraph service between New York and London was started in 1866 with the first successful transatlantic telegraph cable (all the prices are in nominal current dollars of the year considered). A similar drop in price can be seen after telegraph service started between New York City and Tokyo. Additional, there is an important downward and long-term convergence in prices before the telegraph services were discontinued later on.

Table 2-2: Telegraph Rates per Word from New York City

Year	London	Tokyo
1866	$10.00	-
1868	1.58	-
1880	0.50	$7.50
1890	0.25	1.82
1901	0.25	1.00
1924	0.20	0.50
1950	0.19	0.27
1970	0.23	0.31

Source: Cordeiro based on Odlyzko (2000)

Table 2-3: Telephone Rates for a 3-Minute Call from New York City

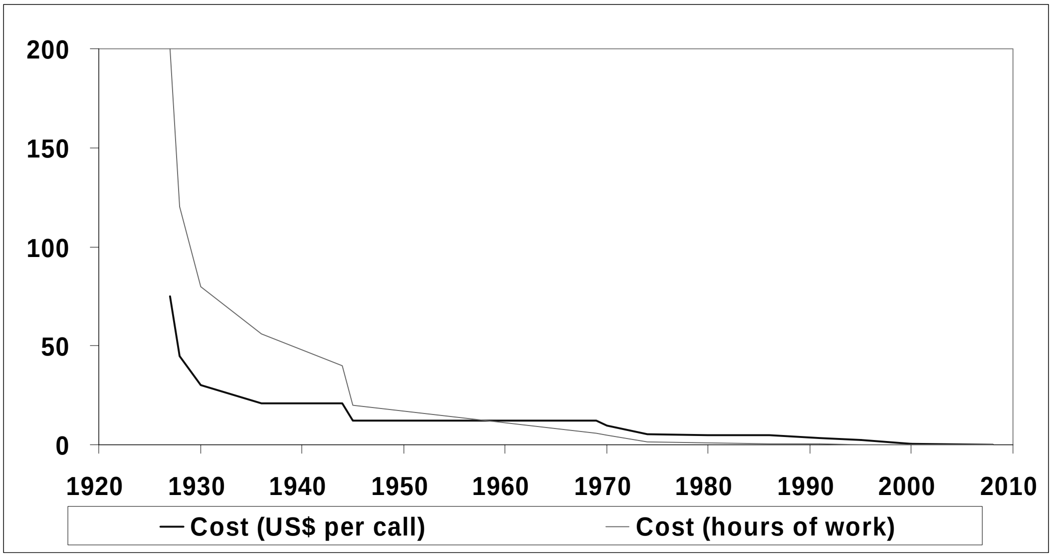
Year	Philadelphia	Chicago	San Francisco
1917	$0.75	$5.00	$18.50
1926	0.60	3.40	11.30
1936	0.50	2.50	7.50
1946	0.45	1.55	2.50
1959	0.50	1.45	2.25
1970	0.50	1.05	1.35

Source: Cordeiro based on Odlyzko (2000)

Just like for telegraph messages, telephone calls have also become much cheaper through time. Table 2-3 shows the costs of a 3-minute, day-time telephone call between New York City and Philadelphia, Chicago and San Francisco. Since the AT&T trans-continental telephone connection was finalized in 1915, the telephone rates between New York City and San Francisco have gone down considerably. Additionally, prices have converged downwards and today most telephone companies in the USA have flat rates and unlimited calling programs that make the marginal cost of calling, to almost any city, equal to almost zero.

Figure 2-4 shows similar results for the telephone rates for a 3-minute call between New York City and London, since 1927 when the first public trans-Atlantic phone call (via radio) was started. Most interesting is to see the bigger drop in prices when measured in hours of work, from almost 200 hours in 1927 to almost nothing today. Indeed, using the new

Figure 2-4: Telephone Rates for a 3-Minute Call between New York and London



Source: Cordeiro based on Odlyzko (2000)

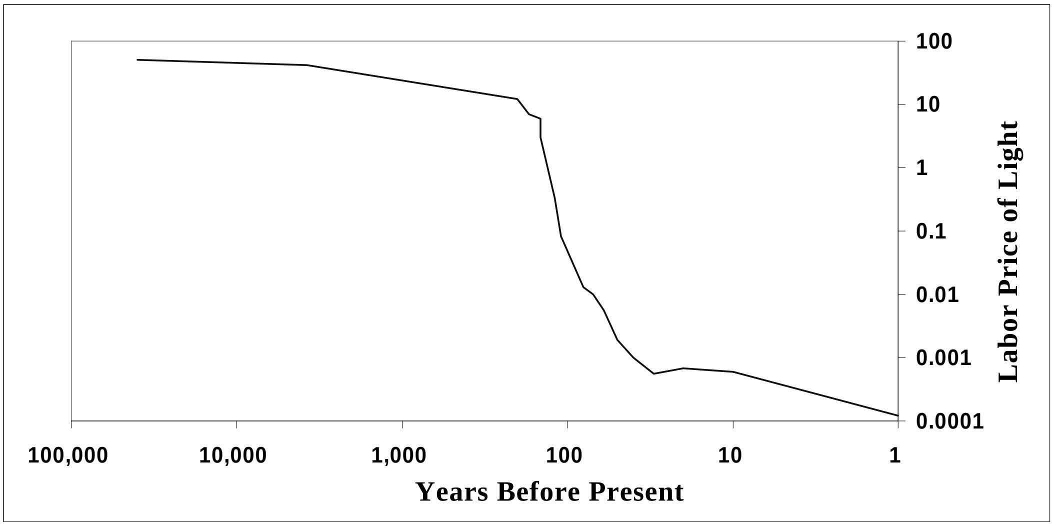
VoIP (Voice over Internet Protocol) services like Skype, it might actually cost basically zero to make such trans-Atlantic calls now.

But not only trans-Atlantic calls might cost today practically zero, but also trans-Pacific calls and international calls to just anywhere with a phone, fixed or mobile, or even a just computer with an Internet connection. Niklas Zennström, the Swedish entrepreneur who co-founded KaZaA peer-to-peer file sharing system and then co-founded in Estonia the Skype peer-to-peer internet telephony network, is famous for saying:

> *The telephone is a 100-year-old technology. It's time for a change. Charging for phone calls is something you did last century.*

Telephone rates have in fact dropped to almost zero in just over a century, but this trend can again be observed in several other sectors. Lighting is an important sector that was studied by Nordhaus (1997), starting briefly with the biological origin of the eyes and their long evolution to allow organisms to use light (since many lower life forms do not have eyes or other light receptors). Nordhaus estimated the price of light as measured in hours of work per 100 lumen hours (lumen is a measure of the flux of light), including estimates for the fires in the caves of the Peking man using wood, the lamps of the Neolithic men using animal or vegetable fat and the lamps of the Babylonians using sesame oil. After reviewing the labor-time costs of candles, oil lamps, kerosene lamps, town gas and electric lamps, he concludes that there has been an exponential decrease of lighting costs, particularly during the last 100

Figure 2-5: Price of Light (Hours of Work per 1000 Lumen Hours)



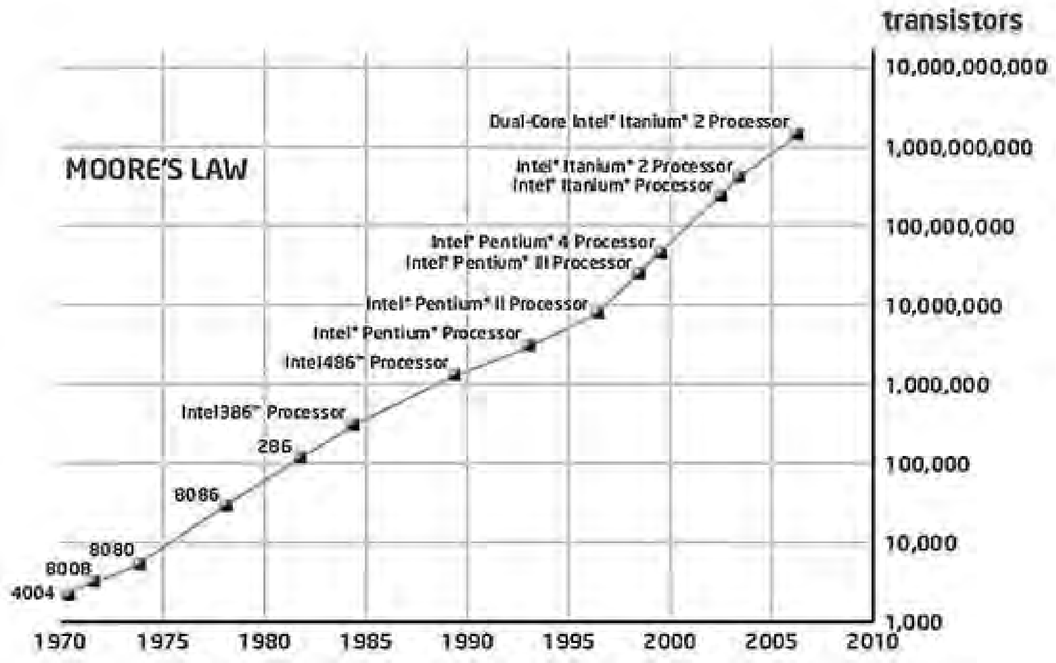
Source: Cordeiro based on Nordhaus (1997) and DeLong (2000)

years. However, some of these outstanding costs reductions, a ten thousand-fold decline in the real price of illumination, have not been captured by the standard price indices, as reiterated by DeLong (2000).

Another example of the exponential increase of capabilities and the corresponding reduction of costs is the commonly called Moore's Law for the semiconductor industry. Caltech professor and VLSI pioneer Carver Mead named this eponymous law in 1970 after Gordon Moore, co-founder of Intel. According to Moore's original observations in 1965, the number of transistors per computer chip is doubling every two years, even though recently this trend has accelerated to just about 18 months recently. Figure 2-6 shows the Moore's Law with an exponential scale in the vertical axis.

Moore's Law and similar conjectures have been observed for the number of transistors per integrated circuit, cost per transistor, density at minimum cost per transistor, computing performance per unit cost, power consumption, hard disk storage cost per unit of information, RAM storage capacity, network capacity and pixels per dollar. In the case of computer flash memories, the Korean company Samsung follows Hwang's Law, named after a vice president of Samsung.

Figure 2-6: Moore's Law



Source: Cordeiro adapted from Intel (2008)[12]

According to Moore himself, his "law" should still be valid for the next 20 years or so, until we reach levels of transistors at the nanoscale.[13] For the telecommunications sector, this is very important since we are currently witnessing the merge and convergence of the information and communications technologies, usually referred together as ICT.

Such trends of increasing capabilities, decreasing costs and convergence are happening not just with ICT, but also with other major industries. For example, there are currently fast price reductions in some innovative energy technologies (with rapid efficiency increases and cost decreases for solar energy and other renewable sources), nanotechnology and biotechnology. The case of biotechnology is also an example of the fast rate of change both in time and costs in order to sequence the human genome. The publicly funded Human Genome Project, originally started as a 15 year project, was estimated to cost about US$ 3

[12] Intel maintains extensive information about Moore's Law in its own web page. Gordon Moore wrote his landmark paper in 1965, when he was still in Fairchild Semiconductors, and before co-founding Intel with Robert Noyce in 1968. See, for example: http://www.intel.com/technology/mooreslaw/index.htm

[13] However, Kurzweil (2005) contends that Moore's Law is just the fifth paradigm in a series of technological changes in the computing industry for over a century. Thus, according to Kurzweil, a new paradigm will emerge that will continue such exponential trend, which he calls the "Law of Accelerating Returns".

Table 2-4: Time and cost to sequence human genome

Year	Cost	Time
2003	$437,000.000	13 years
2007	10,000,000	4 years
2008 (early)	1,000,000	2 months
2008 (late)	100,000	4 weeks
2012	100	2 days

Source: Cordeiro based on Kurzweil (2008)[14]

billion, and it took 13 years, from 1990 to 2003. There was an additional privately funded project led by biologist Craig Venter that took a little less time and a significant lower amount of money. In early 2008, the genome of Nobel Laureate James Watson was published: it took about 2 months and it cost over US$ 1 million. By late 2008, it was possible to sequence a complete human genome in only 4 weeks at a cost of US$ 100,000. Now there are some companies already offering to sequence a general genome for US$ 1,000, and it is estimated that by 2012 it will take just 2 days and cost US$ 100 or less. Table 2-4 shows the diminishing trend in time and costs to sequence the human genome.

Across many technological fields, trends of convergence, increasing efficiencies and decreasing costs can be observed. They will obviously have a major impact on the continuous economic growth of different countries around the world, from wealthy OECD countries to poor African countries, from Asia to Latin America. Just as the 19th century, which experienced a rate of economic growth unprecedented in human history, was followed by a 20th century with even more growth, the 21st century might have the highest rate of growth yet to be recorded. The recent *Growth Report* commissioned by the World Bank and chaired by Nobel Economist Michael Spence (2008), has actually qualified signs of hope for the future. In fact, the rise[15] of China and India, plus other developing countries, is a reality. This is good news not just for those countries, but for the entire world; as a Chinese saying explains: “a rising tide lifts all the boats”. Telecommunications have played a very important role in faster, cheaper and better connections for all the regions of the world. Now the accumulated knowledge of mankind is becoming reachable, almost for free, from Tokyo to Timbuktu.

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[14] Kurzweil has been monitoring the changes not only in ICT, but also in nanotechnology and biotechnology, including their convergence, for several years. See, for example: http://www.kurzweilai.net/news/frame.html?main=/news/news_single.html?id%3D8527

[15] Some Chinese and Indians actually talk not about the “rise”, but about the “re-emergence” of China and India, since they are not just rising but recovering their important status as shown by the historical record for most of human civilization.

CHAPTER 3: Country Data and Comparative Analysis

All things appear and disappear because of the concurrence of causes and conditions. Nothing ever exists entirely alone; everything is in relation to everything else.

Buddha, Indian philosopher, circa 500 BCE

What we observe is not nature itself, but nature exposed to our method of questioning.

Werner Heisenberg, Nobel Prize in Physics, 1932

3.1. Sample Countries

The principal purpose of this paper is to compare the long-term development of telephones and economic growth, with an emphasis on Latin America and Asia. Therefore, particular stress is placed on the major Latin American and Asian countries. The countries included in Latin America are: Argentina, Brazil, Chile, Colombia, Cuba, Mexico, Peru, Uruguay and Venezuela. The economies included in the Asia are: China (the current People's Republic of China, not including Hong Kong, nor Macau), India, Indonesia, Iran, Philippines, South Korea, Sri Lanka, Taiwan (the current Republic of China), Thailand, Turkey and Japan (which was the leading developed country in Asia during the 20th century).

In order to improve and expand the comparative analysis, some major leading and laggard countries from other regions of the world are also included. The leading countries of

Table 3-1: Sample Countries by Region

Latin America	Asia	North America	Oceania	Africa	Europe
Argentina	China	Canada	Australia	Egypt	Austria
Brazil	India	USA	New Zealand	South Africa	Belgium
Chile	Indonesia				Denmark
Colombia	Iran				Finland
Cuba	Philippines				France
Mexico	South Korea				Germany
Peru	Sri Lanka				Greece
Uruguay	Taiwan				Italy
Venezuela	Thailand				Netherlands
	Turkey				Norway
	Japan				Portugal
					Spain
					Sweden
					Switzerland
					U. Kingdom

North America (Canada and the USA), Oceania (Australia and New Zealand) and Europe (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom) are thus considered as well. Africa, as the laggard continent during most of the 20th century, is included by two representative countries where data was available or could be easily reconstructed (Egypt and South Africa). Table 3-1 has a summary of the countries, according to their regions, used in the analysis.

3.2. Data Collection

Historical data is sometimes confusing, contradictory, incomplete, missing or plainly unavailable. However, a careful search was performed country by country, while keeping in mind that many nations have suffered major changes during the 20th century. A quick historical comparison of the countries considered, by region, gives the following results:

Latin American countries had comparatively straightforward histories since they were all theoretically independent (even Cuba after the Spanish and US claims in the late 19th century), their borders have remained mostly stable, and they have been comparatively peaceful.

Asian countries included many colonies during the first half of the 20th century: South Korea and Taiwan were Japanese colonies, the Philippines was an American commonwealth, India and Sri Lanka were British colonies and Indonesia was a Dutch colony. China had a very convoluted history with the fall of their last Emperor, the creation of a republic, the civil war among communists and nationalists, the Japanese occupation, and partial colonization of certain regions (Manchuria by Japan, Hong Kong by the United Kingdom and Macau by Portugal). Additionally, many parts of East and South East Asia were partially occupied by Japan during World War II. Turkey was created as the continuing state after the fall of the Ottoman Empire at the end of World War I, and it included a small but important European region (from Istanbul to the West). Iran and Thailand remained geographically stable, in comparative terms, but they also suffered many changes, including changing their names (Persia became Iran and Siam became Thailand).

North American countries remained internally peaceful during the 20th century. The USA was already independent and Canada became self ruling during the end of last century. The two countries participated actively during both world wars, but their external borders suffered no major changes.

Oceania (Australia and New Zealand) was relatively similar to North America, and the two countries are sometimes referred to as “Western off-shots” as well. Both major countries in Oceania joined the two world wars with the allies, and years later gained peaceful independences from the United Kingdom.

Almost all **African countries** were colonies during the first half of the 20th century (the only two exceptions were Ethiopia and Liberia, which could not be included in this study for lack of reliable data). Both Egypt and South Africa were British colonies that later became independent without major changes in their national borders during last century.

European countries suffered heavily during both world wars. During World War I, there were major border changes, particularly for Austria and Germany, and Finland achieved its independence near the end of the war. During World War II, the devastation in Europe was much bigger and Italy would lose its king (just like Austria and Germany had lost theirs after WWI), a trend followed years later by Greece as well. Spain had its own bloody civil war, and only Sweden and Switzerland managed to remain theoretically neutral during both wars.

The data gathered for this long-term study was concentrated on three main variables:[16]

POP: population,

TEL: main fixed telephone landlines, and

GDP: gross domestic product.

The *POP* variable was used to "normalize" the *TEL* and *GDP* variables in per capita terms, giving thus:

TELc: telephones per capita, and

GDPc: GDP per capita.

Most of the data for *POP* and *GDP* come from the updated database maintained by Angus Maddison (2007) and now available free in the Internet. However, the numbers were cross checked with several national and international information sources. In the cases of countries not included by Maddison since 1900, other sources were utilized. For example, the data from Cuba was mostly adapted from Williamson (2005), Egypt from Yousef (2002) and South Africa from Fedderke et al. (2006).

The TEL telephone statistics are much more complicated, since there is no single complete compilation of such numbers anywhere. In fact, some of the "standard" sources for such data are either very incomplete (like the original first ITU yearbooks and similar AT&T statistics) or plainly wrong (like Mitchell and his first telephone numbers for Hong Kong and the United Kingdom, for example). Therefore, checking, rechecking and cross-checking of all telephone data was very important in this work.

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[16] Many other historical data were compiled, including telegraph and postal data for the telecommunications sector, patent statics as an indicator of technological innovation, together with imports and exports as major economic variables. However, they were not utilized in this study since no clear correlations could be found.

In general, the telephone data collected and revised for this study comes from four different major groupings:

National official sources: like statistical institutes, country ministries and national public telephone companies.

National independent sources: like universities and academic institutions, think tanks, individuals and private telephone companies.

International official sources: like the ITU, League of Nations, United Nations and World Bank.

International independent sources: like regular compilations made by AT&T, Banks[17], Mitchell, world almanacs and international yearbooks.

The author is very grateful to all the help provided by Carmen Reinhart (University of Maryland), Alan M. Taylor (University of California, Davis), Pierre van der Eng (Australian National University), Jeffrey G. Williamson (Harvard University) and Ryan Womack (Rutgers University), who kindly shared some of their important historical databases with me. A debt of gratitude is also owed to the librarians and other personnel of AT&T, ITU and the US Library of Congress, who have been great resources for checking, cross checking and rechecking multiple, and many times, incompatible data.

Once the data was compiled, a major problem was to guarantee that the numbers were actually comparable. This is a usual problem with comparative historical statistics, and it was particularly relevant since the telephone information was measured and reported differently by separate countries. In the early years of telecommunications, during the wave of telegraphs, emphasis was placed on installed telegraph mileage. Later, after the rise of telephones, the emphasis changed to the number of telephone sets (machines) sold. Finally, the focus shifted to the amount of actual separate telephone lines. Measurement thus changed from the original supply side (the builder of telecommunications equipment) to the current demand side (the buyers of the subscriptions).

Since 1975, most countries standardized their statistical reporting based on the number of telephones lines and not the number of telephones sets; and thus the corresponding adjustment was made to all historical data. The ITU has been very influential in promoting a standard for telecommunications measurement since its founding in 1865 as the first international government organization in modern history. At that time, it was called the International Telegraph Union, but its name was changed in 1934 to officially incorporate telephones and other forms of telecommunications, and it became the International Telecommunication Union. Some of the earlier member states of the ITU did not report any data, such as China, which did not do so until the second half of last century. Taiwan was

[17] Banks first compiled the *Cross-National Time Series, 1815-1973* electronically in 1976, and it has fortunately been updated since.

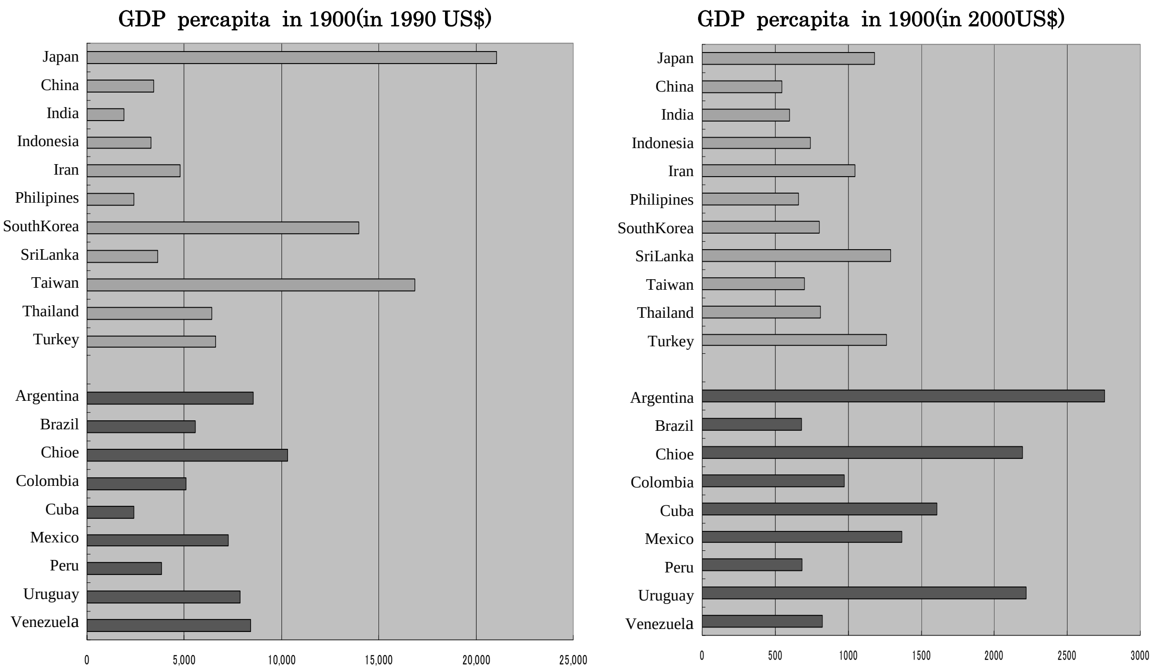
briefly a member of the ITU, but unfortunately its data has ceased to be included. Other sources were used for such special cases.[18]

Appendix 2 shows the historical series compiled for *TELc* and *GDPc* in graphical form for 41 countries over one hundred years, according to the world regions considered. In the case of missing data for select years in some countries, such as the war years, simple linear interpolations were performed. The *TELc* data is presented in a logarithmic scale and the *GDPc* is presented in a linear scale using 1990 International Geary-Khamis dollars.

3.3. Regional and Historical Analysis

The relative performance of Latin America and Asia is the main topic of this research. Accordingly, one major point is to notice that Latin America was relatively richer than Asia, in per capita terms, in the year 1900. At the beginning of the 20th century, the so called

Figure 3-1: Comparative GDP Analysis:
Latin America and Asia in 1900 and 2000 (1990 US$)



Source: Cordeiro based on Appendix 2

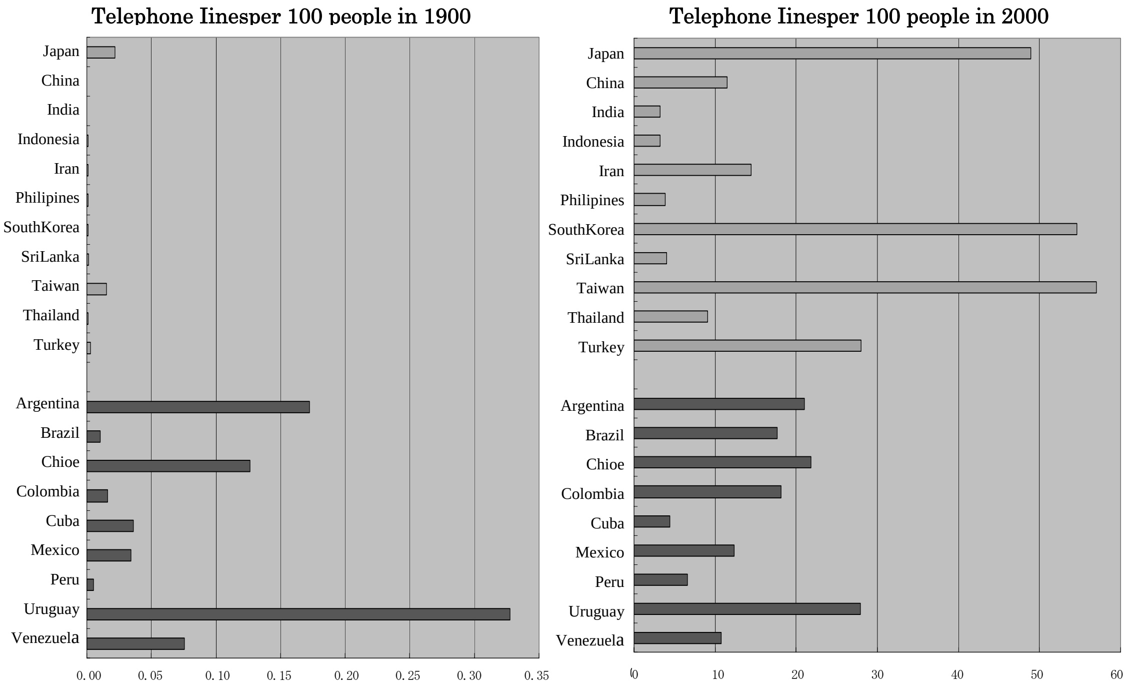
[18] The political realities of many countries are evidenced by the availability and quality of many data found. In the case of China and Taiwan, the differences are very obvious.

Southern Cone countries of Argentina, Chile and Uruguay had living standards similar to those in many European countries, and much higher than any Asian country. In fact, at that time, Japan was slightly poorer than Ceylon (Sri Lanka) and the Ottoman Empire (Turkey). By the year 2000, Asian countries like Japan, followed closely by South Korea and Taiwan, had reached the status of developed nations, while most of Latin America fell behind. Figure 3-1 shows these results graphically.

In terms of telephone industry, the comparison is more striking. Brazil, thanks to its Emperor Pedro II meeting Alexander Graham Bell, became the second country in the world to have Bell telephones in 1876, shortly after the USA. After a quick start, Brazil developed its telephone industry slowly, but even in 1900 it had a larger telephone penetration than any

Asian country, except for Japan and its Taiwan colony. In general, Latin America was far ahead of Asia in number of telephones, per capita, in 1900. In fact, this can be also seen as it was relatively easier to obtain Latin American data than Asian data for the year 1900.[19]

Figure 3-2: Comparative Telephone Analysis:
Latin America and Asia in 1900 and 2000 (telephones per 100 people)



Source: Cordeiro based on Appendix 2

[19] Overall data availability was relatively better for Latin America than for Asia at the beginning of the 20th century.

However, by the year 2000, Asian countries were moving ahead of Latin America in terms of fixed telephone penetration (and a similar trend could be observed for mobile telephone penetration[20]). Figure 3-2 shows these results graphically.

The quick observation of Figures 3-1 and 3-2 is very clear. In general, Latin America was ahead of Asia in 1900. However, 100 years later, the reverse picture could be seen. Thus, the 20th century has been called the "lost century" for Latin America.[21]

[20] Mobile telephone statistics were also compiled, together with Internet subscriptions, but they were not included in this long-term comparative study. Mobile telephone statistics are only available since the 1980s, and Internet data from the 1990s, for most countries.

[21] Cordeiro (2007) makes a more extensive comparison among the different regions of the world between the years 1900 and 2000, with emphasis on the relative position of Latin America.

CHAPTER 4: Statistical Analysis

I hear and I forget. I see and I remember. I do and I understand.

Confucius (孔夫子), Chinese philosopher, circa 500 BCE

There are three kinds of lies: lies, damned lies, and statistics.

Mark Twain, US humorist and writer, 1904

Science cannot solve the ultimate mystery of nature. And that is because, in the last analysis, we ourselves are a part of the mystery that we are trying to solve.

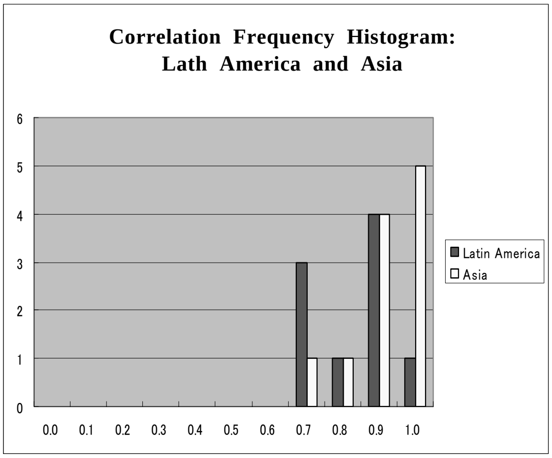
Max Planck, Nobel Prize in Physics, 1918

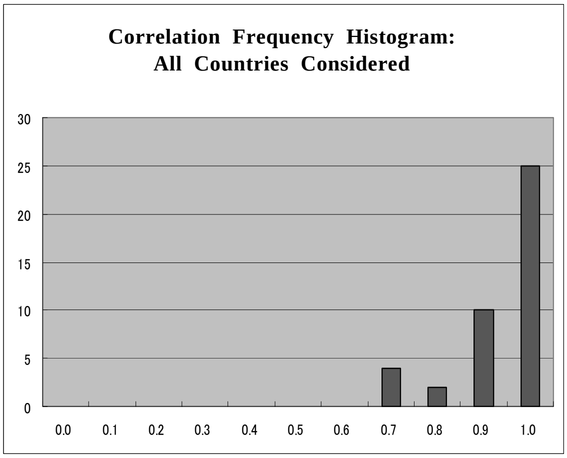
4.1. Correlation Analysis

The best and simplest way to begin a statistical analysis is to perform different kinds of correlations among the variables used. In this case, the *TELc* and *GDPc* variables were correlated for all 41 countries considered. Each historical data series was correlated with its counterpart for each separate country.

Figure 4-1 shows frequency histograms for the correlation coefficients. Both Latin America and Asia have very high correlations, with coefficients over 60 percent (that is, above 0.6 in all cases), but the Asian countries have an overall stronger correlation than the

Figure 4-1: Correlation Frequency Histograms





Source: Cordeiro based on Appendix 2

Latin American countries (the Asian correlation coefficients are more stocked to the right in the horizontal axis of the frequency histogram below on the left). Overall, for all countries considered, there is indeed a very high correlation, as also shown in the histogram below on the right of Figure 4-1.

The additional computations of the Spearman's rank correlation coefficients validate the very high correlations between *TELc* and *GDPc*. The Spearman's rank correlation coefficient is a non-parametric measure of correlation ranking the data, in this case, not using time but magnitude of the variable in the data series.[22] In general, the Spearman's correlation coefficients are higher than the standard correlation coefficients, which indicate the existence of an important time trend in all the data series.[23] Table 4-1 shows the complete results for the standard and Spearman correlation coefficients, both of which show very strong correlations.

Table 4-1: Correlation Analysis

Region (countries)	Correlation	Spearman	Region (countries)	Correlation	Spearman
Latin America			**Oceania**		
Argentina	0.8202	0.9971	Australia	0.9901	0.9807
Brazil	0.7702	0.9985	New Zealand	0.9846	0.9590
Chile	0.9449	0.9981	**Africa**		
Colombia	0.8555	0.9984	Egypt	0.8285	0.9165
Cuba	0.6247	0.9991	SouthAfrica	0.8171	0.9122
Mexico	0.8663	0.9987	**Europe**		
Peru	0.6405	0.9993	Austria	0.9851	0.9117
Uruguay	0.8714	0.9967	Belgium	0.9875	0.9753
Venezuela	0.6019	0.9983	Denmark	0.9902	0.9920
Asia			Finland	0.9818	0.9876
China	0.8747	0.9994	France	0.9466	0.9466
India	0.9329	0.9998	Germany	0.9405	0.9639
Indonesia	0.8617	0.8615	Greece	0.9705	0.9273
Iran	0.6211	0.9372	Italy	0.9806	0.9642
Philippines	0.7287	0.9586	Netherlands	0.9770	0.9564
South Korea	0.9896	0.9471	Norway	0.9838	0.9945
Sri Lanka	0.8807	0.8795	Portugal	0.9527	0.9836
Taiwan	0.9860	0.9439	Spain	0.9857	0.9412
Thailand	0.9250	0.8993	Sweden	0.9954	0.9913
Turkey	0.8530	0.9515	Switzerland	0.9688	0.9895
Japan	0.9937	0.9757	United Kingdom	0.9875	0.9853
North America					
Canada	0.9900	0.9777			
USA	0.9904	0.9868			

Source: Cordeiro based on Appendix 2

[22] The Spearman's correlation assesses how well an arbitrary monotonic function can describe the relationship between two variables, without making any assumptions about the frequency distribution of the variables.

[23] Such time trends will be an important part of the subsequent regression analysis.

4.2. Regression Analysis

Simple correlation analysis is an important technique, but just establishing a correlation between two variables (regardless of its magnitude) is not a sufficient condition to determine a causal relationship (in either direction). In other words, correlation does not imply causality.[24] Another important consideration is the existence of a time trend in all the data, which has to be considered in statistical analysis.

4.2.1. Theoretical Literature Review

Economists such as W. Arthur Lewis (1955) and Simon Kuznets (1966 and 1971) tried to analyze not only economic growth but also structural transformation. Walt W. Rostow developed a theory of development economics based on a linear-stages-of-growth model published in *The Stages of Growth: A Non-Communist Manifesto* (1960). His theory modifies the stages theory of development formulated by Karl Marx and focuses on the accelerated accumulation of capital, through the utilization of both domestic and international savings as a means of spurring investment, as the primary means of promoting economic growth. Rostow's linear-stages-of-growth model postulates that there five consecutive stages of development that all countries must go through during the process of development. These stages are the traditional society, the pre-conditions for take-off, the take-off, the drive to maturity, and the age of high mass-consumption.[25]

Mathematically, the Rostow model can be illustrated with a simple version of the Harrod-Domar model showing that improved capital investment leads to greater economic growth. If ***Y*** is income and ***K*** is capital, then the function becomes:

$$Y = f(K)$$

[24] Furthermore, care must be taken concerning the existence of a spurious relationship in which a correlation between the two variables has no causal connection, yet it may be inferred that they do, due to a certain third, unseen factor (many times referred to as a "confounding factor" or "lurking variable"). The spurious relationship gives an impression of a worthy link between two groups that is invalid when objectively examined.

[25] Such theory was criticized for not recognizing that, while necessary, capital accumulation is not a sufficient condition for development. Therefore, this early and simplistic theory failed to account for political, social and institutional obstacles to development. Furthermore, this theory was developed in the early years of the Cold War and was largely derived from the successes of the Marshall Plan in Europe. However, the conditions found in developing countries were, and are, very different from those found in Europe after World War II.

The simple Rostow model was expanded by Robert Solow and Trevor Swan in order to include labor as a factor of production (represented as ***L***), factor productivity growth (diminishing returns to labor and capital separately, and constant returns to scale for both factors combined, represented as ***a***) and a time-varying technology variable distinct from capital and labor (represented as ***A***). Thus the Solow or neoclassical model can be represented as Cobb-Douglas function such that:

$$Y = A*K^{a}*L^{1-a}$$

Additionally, in order to combine data from both the supply side and the demand side, it is usual to remember the general economic equation for GDP:

$$Y = C + I + G + NX$$

In the simplified equation above, *C* corresponds to consumption, *I* to investment, *G* to government and *NX* to next exports (that is, exports minus imports).

In the 1980s and the 1990s, growth theory advanced again with the theories of Paul M. Romer at Stanford University, Robert E. Lucas at the University of Chicago and Robert J. Barro at Harvard University. Some economists, unsatisfied with the simple explanations by Rostow and Solow, have tried to “endogenize” technology since the 1980s in what is normally called endogenous growth theory.[26]

In terms of infrastructure, in general, and telephones, in particular, simpler analyses have been done to study their impact on economic growth. This is particularly important in the case of long-term historical data series. Thus, reliable data availability is a priority.

In 1963, telecommunications specialist A. Jipp brought to public attention the strong correlation between telephone density (the number of telephones per 100 persons) and what he called the “wealth of nations”. His idea became so popular that many people now use the expression Jipp’s curve and Jipp’s law, which states that that teledensity increases with an increase in wealth or economic development (positive correlation), especially beyond a certain income. In other words, a country's telephone penetration is proportional to its population's buying power. Some telecommunications experts even use the Jipp’s curve not just for fixed telephones but also now for mobile telephones.

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[26] Endogenous growth theory includes mathematical explanations of technological advancement. This model also incorporated a new concept of human capital, the skills and knowledge that make workers productive. Unlike physical capital, human capital has increasing rates of return, there are also constant returns to capital, and economies never reach a steady state. In such models, growth does not slow as capital accumulates, but the rate of growth depends on the types of capital a country invests in. Most research done in this area has focused on what increases human capital (e.g. education) or technological change (e.g. innovation).

The ITU has also done similar analyses since the 1960s and 1970s. Using a very simplified production-function type of equation, they have done a few regression analyses for some countries with reliable data.[27] The former CCITT[28], which was the official French name of the International Consultative Committee on Telephone and Telegraph, used the following equation, using the notion used here:

$$GDPc = a*TELc^{b}$$

That simple equation can be expressed in logarithmic terms as:

$$log(GDPc) = log(a) + b*log(TELc)$$

In a CCITT handbook (1968), they began using such formula and calculated regressions for Sweden since 1900, during different time intervals, and also did cross-country comparisons, similar to Jipp's curve. This became the standard theoretical tool for the few countries with available data then.

In 1983, the World Bank published *Telecommunications and Economic Development*, which became the landmark reference in this field. A Japanese edition was published in 1987 and a Spanish edition in 1988. A second English edition appeared in 1994, which updated some data and expanded some sections. In 1997, the World Bank edited *The Information Revolution and the Future of Telecommunications,* incorporating some of the new developments in information technology and its convergence with telecommunications. The World Bank also dedicated its 1994 *World Development Report* to *Infrastructure for Development*, and its 1999 edition to *Knowledge for Development*. Finally, the United Nations Development Program (UNDP) devoted its 2001 *Human Development Report* to *Making New Technologies Work for Human Development*.[29]

[27] Complete production function equations might be relevant if enough data is available to model appropriately the capital, the labor, the technology, the human capital or other factors considered. However, even in cases where there is enough data, it must be remembered that production functions vary with time, they vary from country to country, and they vary with changes in technology, human capital stock and the like. Therefore, production functions also suffer many limitations not solely based on data availability.

[28] The CCITT has become the ITU Telecommunication Standardization Sector, normally referred to simply as ITU-T.

[29] Many other recent publications by international organizations, like the OECD for advanced economies, have covered different topics about growth and telecommunications, including both empirical research and a few theoretical considerations. This indicates the growing importance of such issues in general, not just for developing countries, but also for developed countries.

4.2.2. Empirical Literature Review

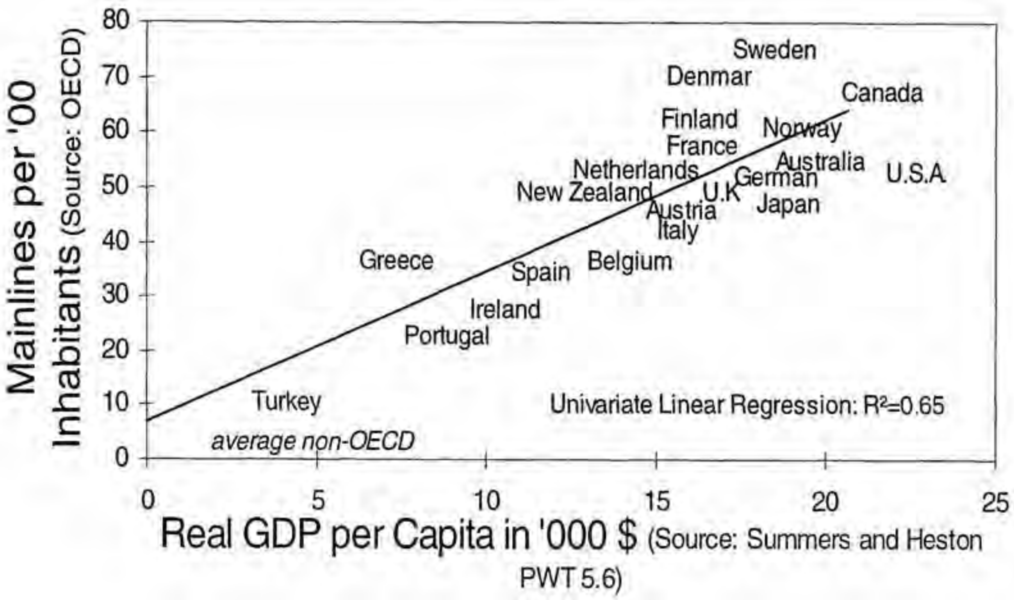
Considerable empirical work was been done about the relationships between economic development and infrastructure, in general, and about economic growth and telecommunications, in particular. Table 4-2 shows a summary of some of the most relevant literature reviewed.

Depending on the available data, different types of statistical analysis have been done by academics and other researchers. Besides correlation analysis and cross-country comparisons, panel data and time-series analysis have been extensively used in the literature. Again, a major point for consideration is the type of statistics available: most panel data analyses have been done for shorter data series with multiple countries, while most time-

Table 4-2: Some Empirical Literature on Infrastructure and Telecommunications

Study	Countries	Data	Conclusions
Calderón and Servén (2008)	136 countries	Panel data, 1960-2005	Infrastructure development has a positive impact on development, with implications
Kularatne (2008)	South Africa	Time series, 1960-2005	Both output and private investment have positive effect on economic expenditure
Fedderke, Perkins and Luiz (2006)	South Africa	Time series, 1875-2001	Infrastructure seems to lead to economic growth, both directly and indirectly
Röller and Waverman (2001)	21 OECD countries	Panel data, 1970-1990	Significant positive causal link from telecommunications to economic growth
Shioji (2001)	USA and Japanese regions	Panel data, 1958-1978	Infrastructure capital has a significant positive effect on long-run output in both
Nourzad (2000)	12 developing and developed countries	Panel data, 1976-1989	Public capital exerts a positive and statistically significant effect on labor
Kneller, Bleaney and Gemmell (1998)	22 OECD countries	Panel data, 1970-1995	An increase in productive expenditure significantly enhances growth
Ramirez (1998)	Chile	Time series, 1960-1993	Public investment has a positive and highly significant effect on growth
Rioja (1998)	7 Latin American countries	Time series, 1970-1995	Infrastructure investment has sizeable positive effects on GDP and private
Devarajan et al. (1996)	43 developing countries	Time series, 1970-1990	Total government expenditure has a positive but statistically insignificant effect on
Ram (1996)	53 developing countries	Panel data, 1973-1980, 1980-1985, 1985-1990	Public investment appears more productive than private investment
Toen-Goet and Jongeling (1994)	USA	Time series, 1960-1990	Public investment on infrastructure has a significant and positive influence on output
Shah (1992)	Mexico	Time series, 1970-1987	Public infrastructure has positive multiplier effect on output
Ford and Poyet (1991)	USA	Time series, 1957-1989	Public investment has a significant and positive effect on private output
Aschauer (1989)	USA	Time series, 1949-1985	Strong and positive relationship between productivity and public investment

Figure 4-2: Jipp's curve for 21 OECD countries (Teledensity and GDP per capita)



Source: Röller and Waverman (2001)

series analyses are for longer data series (regardless of the number of countries available, even if single country analysis has been more common for long-term time series). The following analysis will be using multiple country analysis using long-term time-series analysis.

An excellent panel data analysis for telephones in21 OECD countries was performed by Röller and Waverman (2001). They also included an updated Jipp's curve using the data from the Summers and Heston PWT 5.6 (Penn World Tables version 5.6). Figure 4-2 shows their results closely following Jipp's law.

Fedderke, Perkins and Luiz (2006) performed a very long-term time series analysis with new data compiled for South African infrastructure from 1875 to 2001 (their very complete data set included roads, railways, electricity, fixed telephones, air travel and mobile telephones since the first years when such information was registered in South Africa). More recently, Calderón and Servén (2008) have reviewed panel data for a grand total of 136 countries for which there is data since 1960 (their special focus was on comparisons for Africa and what can be learned from the cumulative experience of many other countries in such a large sample across continents).

Finally, it is worthwhile to emphasize that even though most studies using either time series or panel data analysis show a strong correlation between infrastructure and economic growth, that is not always the case. In fact, some literature considers “crowding out” effects and other factors that actually inhibit or slow down growth. Additionally, even in the majority of the cases when there is high correlation between infrastructure and growth, the causality is not always clear. Sometimes the results seem to indicate that infrastructure causes growth, and sometimes that growth causes infrastructure. Thus, this debate is still open to much discussion among experts.

4.2.3. Methodology and Modeling

In this research, based on the long-term data compiled for 41 countries since 1900, a time series analysis is proposed. The simple equation for each country regression can be summarized as follows, in logarithmic form according to the literature reviewed:

$$log(GDPc) = log(a) + b*log(TELc)$$

First of all, the unit root tests were performed for the original variables considered. As expected, and as it is common in many econometric data series, there was a unit root problem since the original *GDPc* and *TELc* variables are not stationary and show a time trend. The original series *GDPc* and *TELc* are I(1) vectors, but the logarithmic variables *log(GDPc)* and *log(TELc)* are I(0) vectors and stationary.

For each of the countries considered, the ADF (Augmented Dickey-Fuller) and the PP (Phillips-Perron) tests were performed in the original and logarithmic variables, in order to verify if they were I(1) and I(0) variables.

4.2.3.1. Johansen Cointegration

In order to do a standard regression analysis with two (or more) variables using vector auto regressions (VAR), it is fundamental to verify whether the variables are cointegrated or not. The Engle-Granger cointegration test can be used for two variables, or the more general Johansen cointegration test. The Johansen test (1988 and 1991) was chosen for its generality and simplicity.[30]

The summary results of the Johansen cointegration tests are shown in Table 4-3. It can be seen that there are some general patterns concerning cointegration for the *log(GDPc)* and *log(TELc)* variables. In North America and Oceania, there was cointegration between the two variables for each country. In Africa and Latin America (except for Cuba, which has some dubious data), there was no cointegration between the two variables in the countries

[30] The complete regression analyses were performed using the EViews, version 6, statistical package. The Johansen cointegration test is performed automatically in EViews, while the Engle-Granger cointegration test has to be done manually on the residuals of the regressed variables.

Table 4-3: Johansen Cointegration Summary

Existence of Cointegration	Region (countries)
Yes	**North America** (Canada, USA) **Oceania** (Australia, New Zealanad)
Some (yes)	**Asia** (India, Philippines, South Korea, Sri Lanka, Thailand, Japan) **Europe** (Belgium, Germany, Norway, Switzerland)
No	**Africa** (Egypt, South Africa) **Latin America** (Argentina, Brazil, Chile, Colombia, Mexico, Peru, Uruguay, Venezuela)

Source: Cordeiro based on Appendix 3

considered. In Asia and Europe, the pattern is not so obvious and there are some countries that show cointegration of the variables in Asia (India, Philippines, South Korea, Sri Lanka, Thailand and Japan) and also in Europe (Belgium, Germany, Norway and Switzerland). These complete results can be seen in Appendix 3. The cointegration results were computed for both the Trace and the Max-Eig (Maximum Eigenvalue) tests, comparing the results for lag 2 and lag 4, and using both trend and no trend in the cointegration equations. The AIC (Akaike Information Criterion) and the SIC (Schwarz Information Criterion) were considered for the selection of the lags, and the most common lag, under both criteria, was lag 2.[31]

4.2.3.2. Granger Causality

After cointegration was tested separately for each country, the regressions were performed using VAR (vector auto regression) for countries with no cointegration and VEC (vector error correction model) for countries with cointegration between the two variables *log(GDPc)* and *log(TELc)*.

Then the Granger causality was checked in order to see if *log(GDPc)* Granger causes *log(TELc)* or if *log(TELc)* Granger causes *log(GDPc)*. The summary results for the Granger causality are shown in Table 4-4. It can be seen that there is no general pattern concerning

[31] Lag 2 was eventually used in general since it was the "common denominator" among all countries considered. The results with alternative lags were checked for comparisons, as seen in Appendix 3, but there was no major difference with alternative lags of mostly 1, 2, 3 and 4.

Granger causality for the *log(GDPc)* and *log(TELc)* variables. In North America and Oceania, there was Granger causality from *log(GDPc)* to *log(TELc)*, using the VEC since the two variables were cointegrated. In the two African countries considered, there was Granger causality from *log(GDPc)* to *log(TELc)*, but using simple VAR since the two variables were not cointegrated. In Latin America, Asia and Europe, there were very mixed results, and there seems to be no common pattern on Granger causality, but there were more examples of Granger causality from *log(GDPc)* to *log(TELc)* than from *log(TELc)* to *log(GDPc)*, for both cointegrated (VEC model) and not cointegrated variables (VAR model). In Asia, only Thailand has Granger causality from *log(TELc)* to *log(GDPc)*. In Latin America, both Chile and Uruguay show Granger causality from *log(TELc)* to *log(GDPc)*. And in Europe, Austria, Germany, Netherlands, Portugal, Sweden, Switzerland and the United Kingdom show Granger causality from *log(TELc)* to *log(GDPc)*. Switzerland is a unique case among the countries considered since it is the only one that actually shows Granger causality in both directions. Finally, there are also some countries that do not exhibit Granger causality in any direction, namely: Argentina, Cuba, Peru and Venezuela in Latin America, Iran, Philippines and Taiwan in Asia, and Belgium, Denmark, Finland and Greece in Europe.

These complete results can be seen in Appendix 4. The Granger causality results were computed using a standard lag of 2 for all countries, once it became evident that such was the common pattern after the AIC and SIC were reviewed.[32] All the results shown were for a statistical significance of 5%, even if a few more causality relations could have been included using a significance level of 10%.[33]

In terms of the varied results for the Granger causality, it might be due to the availability of only two variables, and also due to the use of long time series in such different countries. Nonetheless, dividing the time series in shorter periods seems to give the same results for most countries.[34] Thus, the conclusion here is that there is no common and general pattern for the Granger causality from *log(TELc)* to *log(GDPc)*, nor from *log(GDPc)* to *log(TELc)*, for the countries studied in the time period analyzed.[35]

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[32] The results were compared for both the VAR and the VEC models in cases where cointegration might have been possible. Additionally, different lags were compared according to the AIC and SIC: lags 1, 2, 3 and 4 for the VEC and just lags 2 and 3 for the VAR. The AIC tended to give longer lags, while the SIC gave shorter lags, in average, but always close to lag 2 for both criteria. Therefore, lag 2 was chosen for uniformity among all countries considered, even if the results with alternative lags were checked for comparisons, as seen in Appendix 4, but there was no major difference with alternative lags.

[33] Most of the literature reviewed also used significance levels of 5%.

[34] An obvious separation point for the time series of many countries is before and after WWII; however, most countries give similar results for such shorter time series as well.

[35] However, for the countries and period considered, there is more apparent Granger causality from *log(GDPc)* to *log(TELc)* than from *log(TELc)* to *log(GDPc)*.

Table 4-4: Granger Causality Summary

Country	Does not Granger cause		Method
	TEL > GDP (5% significance)	GDP > TEL (5% significance)	Lag 2
Latin America			
Argentina	No	No	VAR
Brazil	No	Yes	VAR
Chile	Yes	No	VAR
Colombia	No	Yes	VAR
Cuba	No	No	VEC
Mexico	No	Yes	VAR
Peru	No	No	VAR
Uruguay	Yes	No	VAR
Venezuela	No	No	VAR
Asia			
China	No	Yes	VAR
India	No	Yes	VEC
Indonesia	No	Yes	VAR
Iran	No	No	VAR
Philippines	No	No	VEC
South Korea	No	Yes	VEC
Sri Lanka	No	Yes	VEC
Taiwan	No	No	VAR
Thailand	Yes	No	VEC
Turkey	No	Yes	VAR
Japan	No	Yes	VEC
North America			
Canada	No	Yes	VEC
USA	No	Yes	VEC

Country	Does not Granger cause		Method
	TEL > GDP (5% significance)	GDP > TEL (5% significance)	Lag 2
Oceania			
Australia	No	Yes	VEC
New Zealand	No	Yes	VEC
Africa			
Egypt	No	Yes	VAR
South Africa	No	Yes	VAR
Europe			
Austria	Yes	No	VAR
Belgium	No	No	VEC
Denmark	No	No	VAR
Finland	No	No	VAR
France	No	Yes	VAR
Germany	Yes	No	VEC
Greece	No	No	VAR
Italy	No	Yes	VAR
Netherlands	Yes	No	VAR
Norway	No	Yes	VEC
Portugal	Yes	No	VAR
Spain	No	Yes	VAR
Sweden	Yes	Yes	VAR
Switzerland	Yes	No	VEC
United Kingdom	Yes	No	VAR

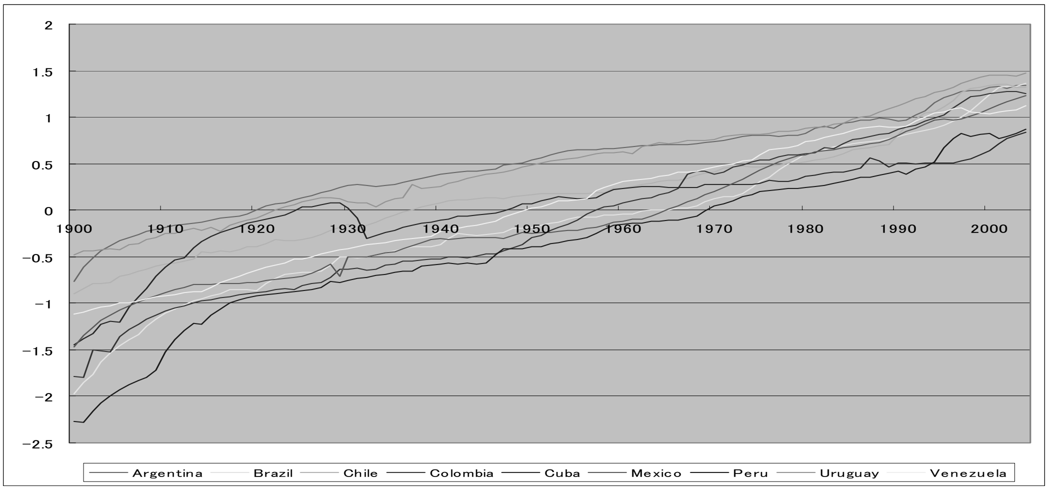
Source: Cordeiro based on Appendix 4

4.3. Convergence Analysis

Besides correlation and causality analysis, it is also important to verify if there is convergence across the countries within the regions and across the regions in the world.

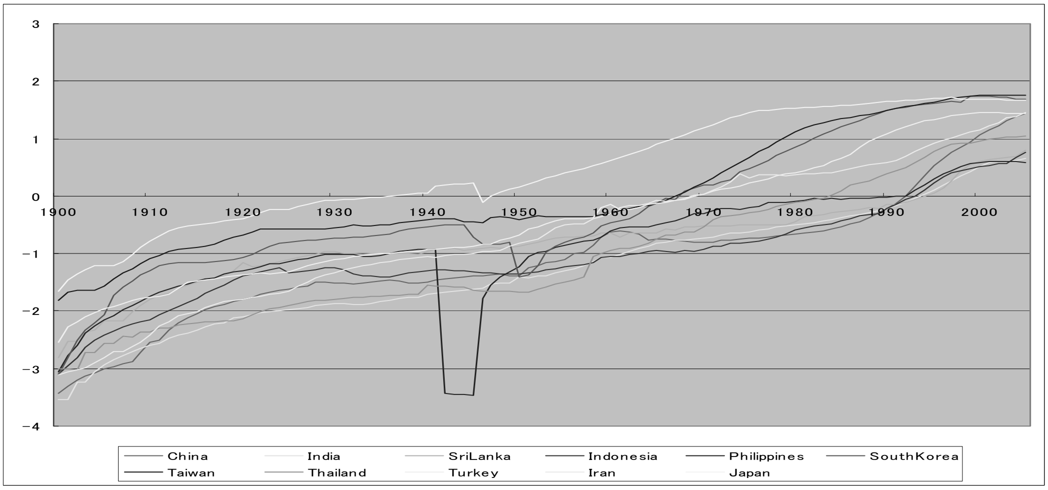
Figure 4-3 shows the general convergence (measured as the *log(TELc)* variable) happening in the Latin American countries (even including Cuba which is a statistical "telephone outlier" in the region). Figure 4-4 shows the convergence in Asia, which was heavily disrupted by WWII (in the extreme case of the Philippines, the number of telephones reported dropped to almost zero during the Japanese occupation) and then the slowdown in China and other countries in the 1950s, while other countries moved faster in the 1970s. However, the general convergence pattern can easily be recognized during the last two decades.

Figure 4-3: Latin America Convergence



Source: Cordeiro based on Appendix 2

Figure 4-4: Asia Convergence[36]



Source: Cordeiro based on Appendix 2

Figure 4-5 shows the convergence across Europe, which is very evident, even including the major disruptions created by WWI and particularly WWII. In fact, Europe looks like a "textbook case" of telephone convergence. Finally, Figure 4-6 shows the overall pattern of world convergence, including the countries considered in North America, Oceania and Africa.

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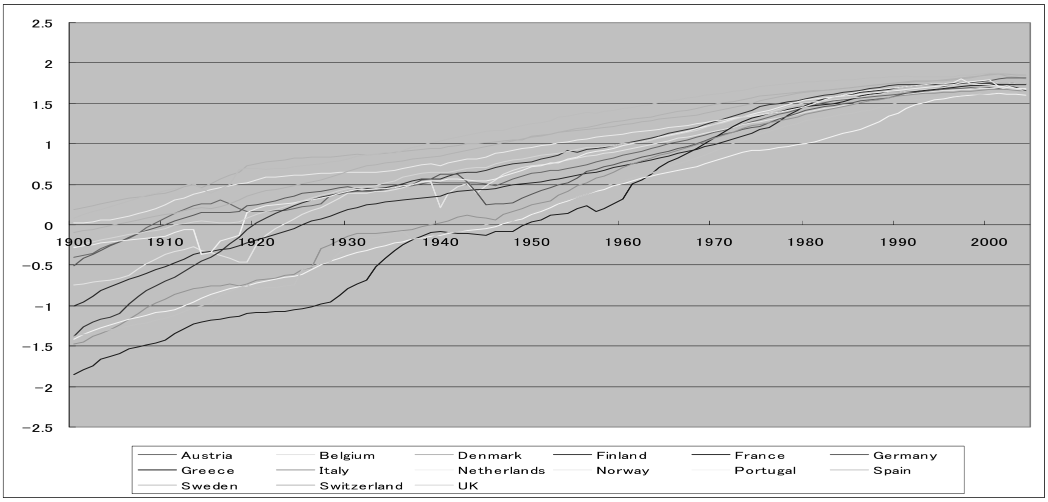
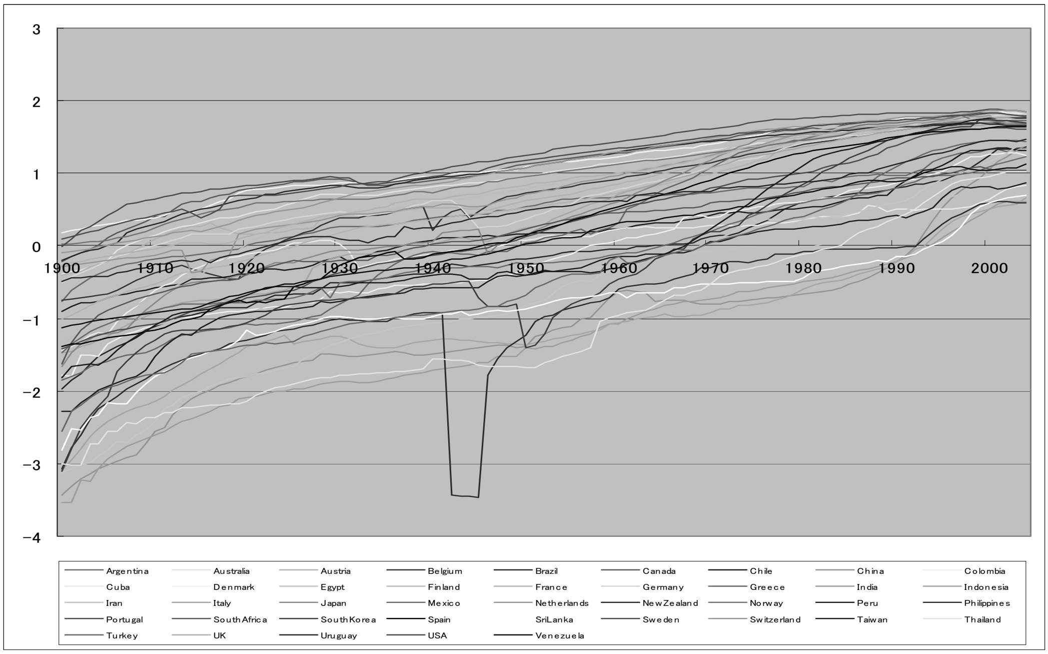
[36] The Philippine Long Distance Corporation (PLDC) registers almost no telephones in the Philippines during the Japanese occupation period in WWII, but such numbers might not be reliable.

Figure 4-5: Europe Convergence



Source: Cordeiro based on Appendix 2

Figure 4-6: World Convergence



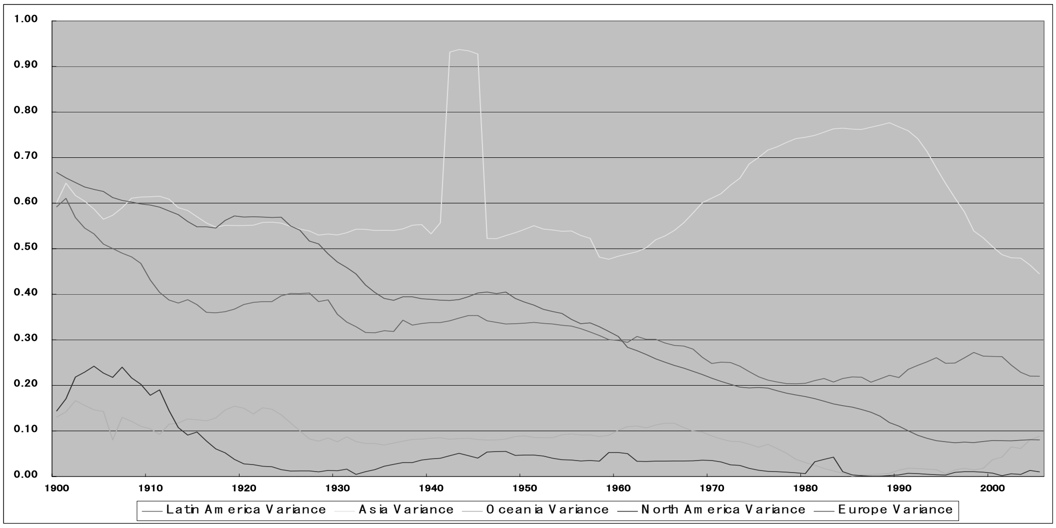
Source: Cordeiro based on Appendix 2

The traditional theory of economic convergence has been refined in the last decades. Besides the more traditional convergence discussed before, usually called β convergence (when poorer countries "catch up" with richer countries), now academics also talk about σ convergence (when the cross-country dispersion declines over time as well).[37] For example, β convergence can be measured by the direct relationship between variables like *log(TELc)*, and σ convergence can be measured by the standard deviation of *log(TELc.)*, which better indicates the rate of change of *TELc*, among the different countries.

Normally, β convergence tends to generate σ convergence, but this process might be offset by new disturbances that tend to increase dispersion. Therefore, σ convergence might be a better indicator of real convergence across countries through time.

Figure 4-7 shows the results of σ convergence among the countries in the different regions. The countries in North America (Canada and the USA) and in Oceania (Australia and New Zealand) exhibit small standard deviations of *log(TELc)*, which corroborates that they follow similar patterns and rate of change for *TELc*. Europe once again shows a "textbook case" of σ convergence, and Latin America is close behind (even including Cuba which, as statistical outlier in the region distorts somehow the results). Asia exhibited some σ convergence until WWII, when some countries moved quickly forward, while others remained behind. Fortunately, there has been σ convergence in Asia for the last two decades.[38]

Figure 4-7: Variance of Convergence by Regions



Source: Cordeiro based on Appendix 2

[37] See, for example, the second edition (2004) of. *Economic Growth* by Barro and Sala-i-Martin.
[38] The African countries are not included since Egypt and South Africa are not representative enough of the African continent in order to compute standard deviations (more countries, or more representative countries, are needed for the standard deviation to make much sense).

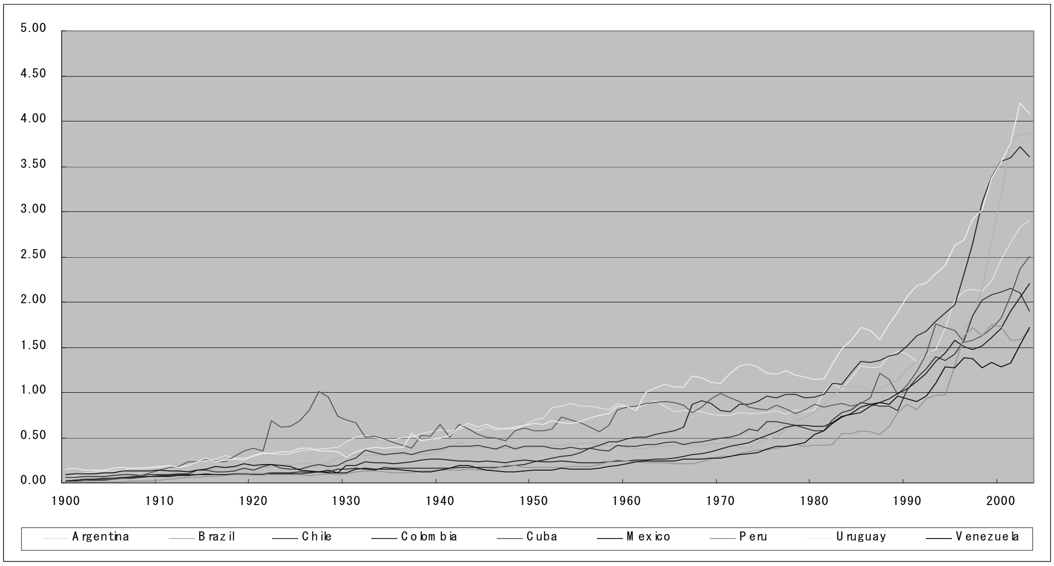
The previous analyses indicate that, generally speaking, there is both β convergence and σ convergence across the regions and across the world. This is an important result in terms of understanding the growing level of telephone penetration in most countries.

4.4. The Penetration of Telephones

From the previous analysis, there seems to be a very high correlation, high convergence and moderate causality between the *TELc* and *GDPc* variables considered for 41 countries since 1900. This compares relatively well with the current literature reviewed. An additional test is to try to find other patterns using a different type of analysis, in this case, calculating the “economic” penetration of telephones as the ratio of *TELc* to *GDPc* for the different countries across the 20th century.

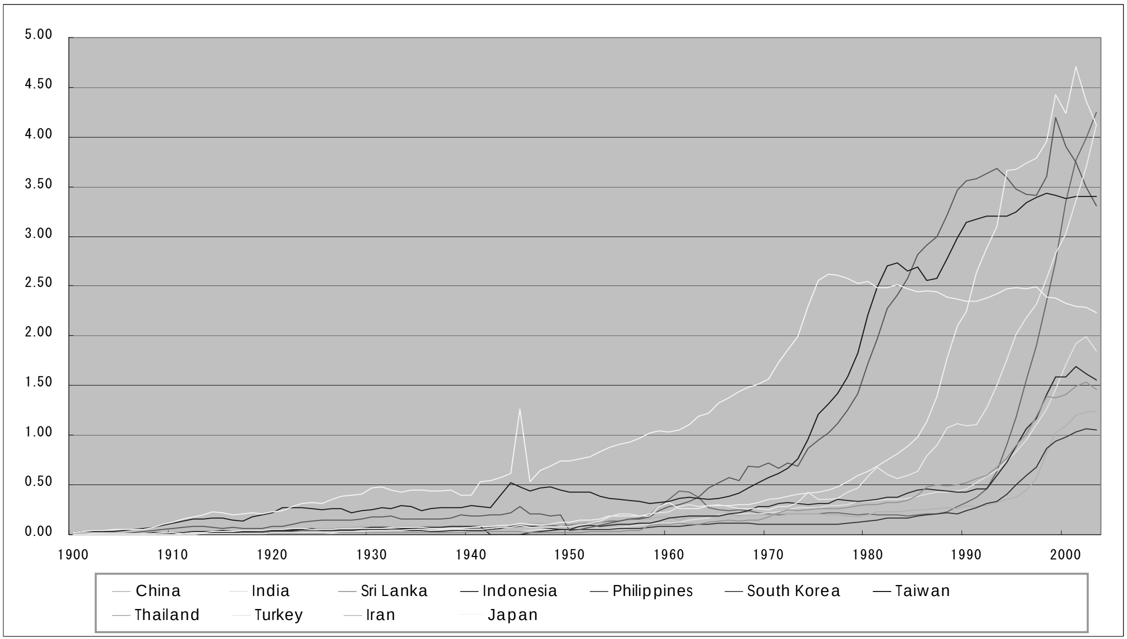
Figure 4-8 shows the ratio of *TELc* to *GDPc* for the Latin American countries. In general, it can be induced that the wealthier the countries become through the years, the higher the telephone penetration. The rapid “rise” of this ratio for Cuba during the 1920s, and its fall since the 1930s, also compares well with the consistent increases of Argentina and Uruguay, for example, as relatively wealthy country countries in the region. Figure 4-9 shows the same ratio for Asian countries. The first country in Asia to achieve high levels was Japan, followed soon by a second wave comprising Taiwan and South Korea, and then by a third wave of other Asian countries, as the “Flying Geese Paradigm” would indicate. It is also

Figure 4-8: Ratio of Telephones per GDP (per capita) in Latin America



Source: Cordeiro based on Appendix 2

Figure 4-9: Ratio of Telephones per GDP (per capita) in Asia

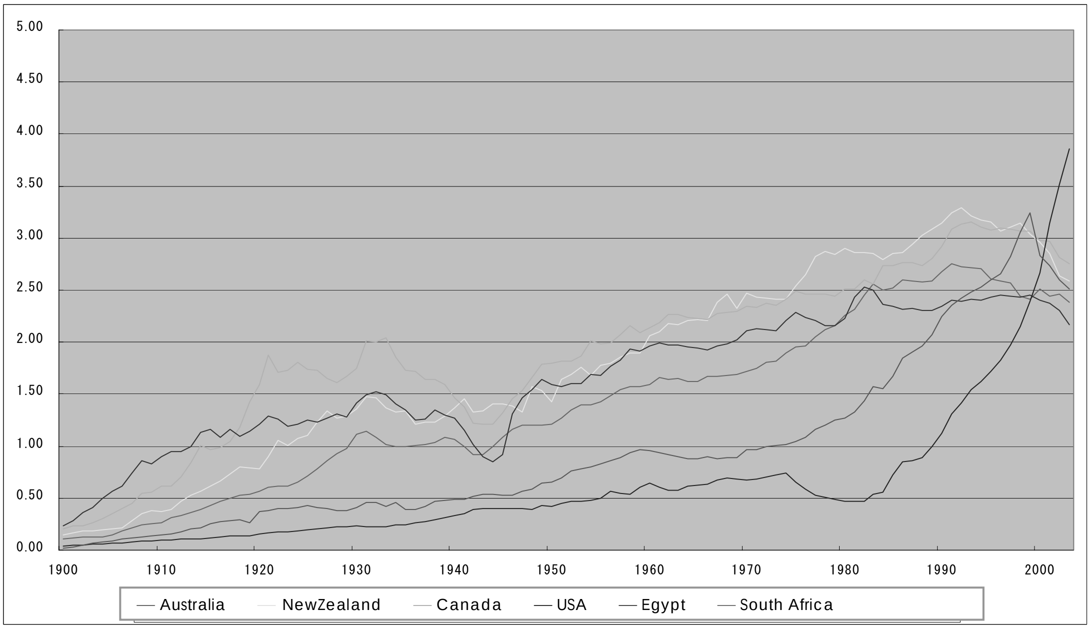


Source: Cordeiro based on Appendix 2

interesting to notice that after a certain level, the curves seem to flatten and they might even decrease (in part due to the later appearance of mobile telephones). For example, Japan's curve flattens in the 1980s, while for Taiwan and South Korea it happens in the 1990s.

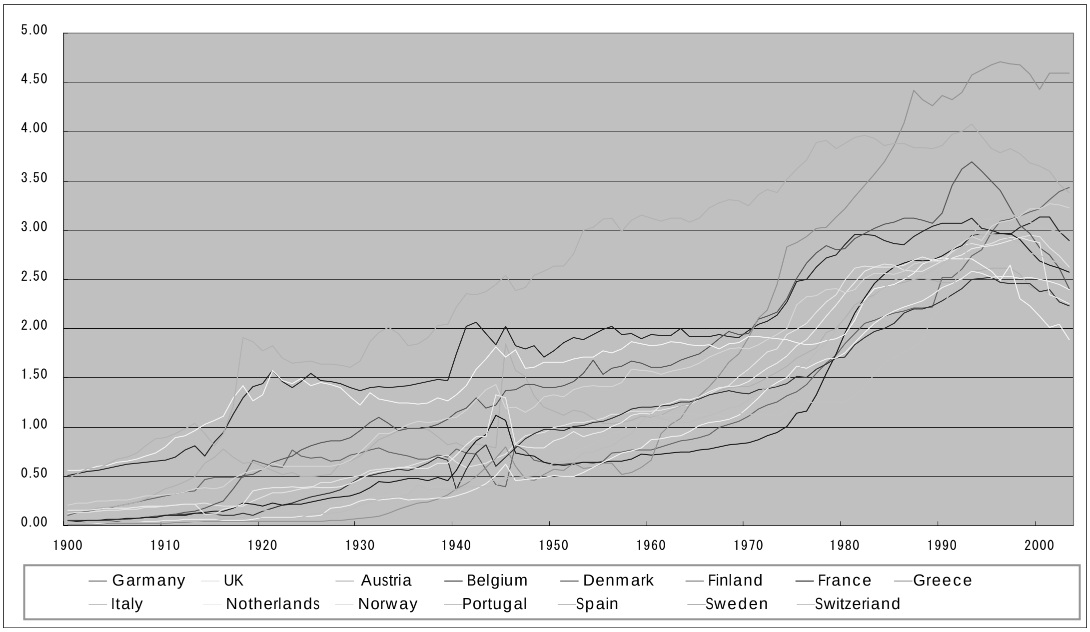
Figure 4-10 shows the ratio of *TELc* to *GDPc* for the considered countries in North America, Oceania and Africa. It can easily be seen that the first two countries to "rise" were the USA and Canada, followed by the two "Western off-shots" in Oceania (New Zealand and Australia), and finally by the two African countries in the sample (South Africa and Egypt). The flattening (and maybe eventual decline) of the curves can also be observed in the countries in North American and Oceania. Finally, Figure 4-11 shows the curves for the European countries. It can be seen that the first countries to rise were three Nordic countries (Sweden, Norway and Denmark), followed by other relatively advanced countries, and finally by the poorer European countries. The rise, leveling off and eventual decline (or substitution of fixed telephones by mobile telephones) of the ratio of *TELc* to *GDPc* can be analyzed in the measure that the countries became wealthier.

Figure 4-10: Ratio of Telephones per GDP (per capita) in North America, Oceania and Africa



Source: Cordeiro based on Appendix 2

Figure 4-11: Ratio of Telephones per GDP (per capita) in Europe



Source: Cordeiro based on Appendix 2

The ratio of *TELc* to *GDPc* does not necessarily imply any causality, but similar patterns have been encountered for other products in countries that become wealthier. From that point of view, maybe fixed landline telephones were considered a “luxury product” some time during their history (just like mobile telephones were almost a luxury item when they first appeared). However, as GDP has increased in most countries, so has increased the telephone penetration even faster, which is clearly indicated by the increase of the ratio between the *TELc* numerator and the *GDPc* denominator. Eventually a “plateau” level is reached, which might resemble a saturation point for the technology, and its eventual decline. This pattern is consistent with the ideas of technology diffusion and the usually called “S curve” of technology adoption.[39]

The beauty of the fixed landline telephones, for the purpose of this analysis, is that the main technology remained basically the same for over a century, until a major technological disruption was created by the arrival of the mobile telephone systems.[40] But the old telephone system was the technology that opened telecommunications to the average person and that interconnected people around the world in real time for the first time in history.

[39] One of the classical studies about technology and economics is Rosenberg (1983), and a more updated version is presented by Ruttan (2001).

[40] Fixed landline telephones are now decreasing in most countries around the world, both in developed and in developing countries. In fact, in lest than 20 years, the total number of mobile telephones already surpassed the total number of fixed telephones in the world.

CHAPTER 5: Conclusions and Future Possibilities

Study the past, if you would divine the future.

Confucius (孔夫子), Chinese philosopher, circa 500 BCE

It is my heart-warm and world-embracing Christmas hope and aspiration that all of us, the high, the low, the rich, the poor, the admired, the despised, the loved, the hated, the civilized, the savage (every man and brother of us all throughout the whole earth), may eventually be gathered together in a heaven of everlasting rest and peace and bliss, except the inventor of the telephone.

Mark Twain, *Boston Daily Globe*, Christmas Greetings: December 25, 1890

The empires of the future are the empires of the mind.

Winston Churchill, British Primer Minister, 1944

5.1. Implications for the Future

The history of telecommunications suggests strongly that there is a very high correlation between the number of telephone lines and economic growth during the 20th century. Over the long-term, the fixed telephone landlines network has remained a relatively stable communication system and it has also become a landmark in the telecommunications history of human civilization. In fact, the 20th century could be called the century of the telephone for the telecommunications industry, just like it was the century of oil for the energy industry.

There are also some significant simple causality relations between telephones and GDP growth, as evidenced by the previous statistical analysis. However, the relationships are not always the same and not necessarily unidirectional. For the 41 countries considered here, and for the 100 year period analyzed, the causality sometimes goes from telephones to GDP, but more often it goes from GDP to telephones. Nonetheless, some sort of relationship is certainly present, and it might probably increase with time, together with the increase in interconnectivity between individuals, institutions and nations.

The continuous growth of ICT is worth to be noticed. From its very humble human beginnings as smoke signals and drum beats, telecommunications has grown into a modern industry representing 3% of the world economy. Telecommunications is also one of the fastest growing sectors, particularly among the poorest countries, who are just jumping from no telephones to mobile telephones and soon wireless Internet connections. In fact, some of the highest growth rates of cellular networks are in poor African countries that are completely bypassing expensive landlines and they are leapfrogging into newer, better and cheaper telecommunication systems. And the mobile telephones are having a positive impact on growth, as described by Waverman, Meschi and Fussi. (2005):

> *The growth dividend of increasing mobile phone penetration in developing countries is therefore substantial. All else equal, the Philippines (a penetration rate of 27 percent in 2003) might enjoy annual average per capita income growth of as much as 1 percent higher than Indonesia (a penetration rate of 8.7 percent in 2003) owing solely to the greater diffusion of mobile telephones, were this gap in mobile penetration to be sustained for some time. A developing country which had an average of 10 more mobile phones per 100 population between 1996 and 2003 would have enjoyed per capita GDP growth that was 0.59 percent higher than an otherwise identical country.*
>
> *For high-income countries, mobile telephones also provide a significant growth dividend during the same time period. Sweden, for example, had an average mobile penetration rate of 64 per 100 inhabitants during the 1996 to 2003 period, the highest penetration of mobiles observed. In that same period, Canada had a 26 per 100 average mobile penetration rate. All else equal, we estimate that Canada would have enjoyed an average GDP per capita growth rate nearly 1 percent higher than it actually was, had the mobile penetration rate in Canada been more-than-doubled.*

The 0.59 percent increase in GDP growth is significant for developing countries, as well as the smaller rate for developed countries, which is also a sign of rapid convergence in mobile telecommunications.[41] Mobile telecommunications are indeed powering a peaceful economic revolution in poorer countries, where people might not even know how to read and write. For example, illiterate farmers and merchants in Africa and India are using their new mobile telephones to make better decisions about the prices of their outputs and the costs of their inputs. The same for fishermen who, using their mobile telephones, find out about weather conditions and higher demand for certain products, for example, changing thus their daily decisions based on more informed and immediate sources of knowledge.

Telecommunications are once again reducing the transaction costs and increasing the amount of available information to all people, even illiterate people.[42] The additional

[41] According to The Economist (May 10, 2007), Waverman repeated later his results with another model, and still got a 0.44 percentage points of additional GDP growth for an extra 10 percentage points in mobile telephone penetration, which is a reduction from his earlier findings but not statistically significant. See, for example: http://www.economist.com/finance/displaystory.cfm?story_id=9149142

[42] Transaction costs are indeed an important factor to consider when studying the telecommunications sector. The classic work about transaction costs is Coase (1937) and a modern analysis for telephones can be found in Norton (1992).

convergence of information and communications technologies and development economics has created a new interdisciplinary research field known as ICT4D (Information and Communications Technologies for Development), which investigates how to transform the so called "digital divide" into a "digital dividend". The United Nations has taken a special interest in this field, just like financial organizations (for example, the World Bank), academic institutions (like the University of California, Berkeley), private foundations (like the Bill & Melinda Gates Foundation), and many government and non-government organizations (NGO) in several countries. Some initiatives like the OLPC (one laptop per child)[43] by Nicholas Negroponte at the MIT Media Lab are widely known, but they are just the tip of the iceberg of the many possibilities offered by the new technologies. In fact, the newer generations of telephones will probably be better than many current laptops, and also faster, better and cheaper. Additionally, the technological convergence will continue adding new features to the telephones of the future.

5.2. An Interconnected World

The world is increasingly becoming an interconnected place. British author Frances Cairncross (1997) has considered *The Death of Distance: How the Communications is Revolution will Change our Lives*. American author Thomas Friedman (2005) has written *The World Is Flat: A Brief History of the Twenty-First Century*. Technology experts Tapscott and Williams (2006) have explained the new economy called *Wikinomics: How Mass Collaboration Changes Everything*. The fact is that the world is indeed becoming more interconnected, and perhaps a new economy is also emerging based on more open source projects and sharing of knowledge. The far-fetched success not just of mobile telephones, but also of the Internet, and newer applications like Google and Wikipedia, is a clear indication of the faster changes to come, both in telecommunications and in the more general and converging ICT fields.[44]

The theory of network effects should be considered in order to understand the full potential of the interconnected world. Theodore Vail, president of AT&T from 1885 to 1889 and again from 1907 to 1919, was an early proponent of the importance of network externalities. More recently, Robert Metcalfe (co-inventor of Ethernet and co-founder of 3Com) has popularized the concept as Metcalfe's law stating that the value of a telecommunications network is proportional to the square of the number of users of the system (n^2). Metcalfe's law follows a considerable improvement over Sarnoff's law, which

[43] The first version was expected to cost only US$ 100 per laptop, but it ended up being closer to US$ 180. The second version might actually be closer to the original US$ 100 once there is enough mass production, but now there are many additional competing projects.
[44] For yet another modern viewpoint about networks, see Benkler (2006): *The Wealth of Networks*.

states that the value of a broadcast network is proportional to the number of viewers (*n*). David Sarnoff, a longtime executive of RCA and founder of NBC, conceived his law based on his practical network experiences.

Metcalfe's law explains many of the network effects of communication technologies and networks such as the Internet and social networking. This law has often been illustrated using the example of fax machines: a single fax machine is useless, but the value of every fax machine increases with the total number of fax machines in the network.

Metcalfe's law has been criticized for overestimating the total number of contacts and confusing it with the *potential* number of contacts. For example, Odlyzko and Tilly (2005) emphasize that the social utility of a network depends upon the number of nodes really *in contact*. Nodes that do not interact, which are many, do not contribute to the total number of contacts. Thus, they argue, that the (n^2) term is actually closer to ($n*log(n)$):

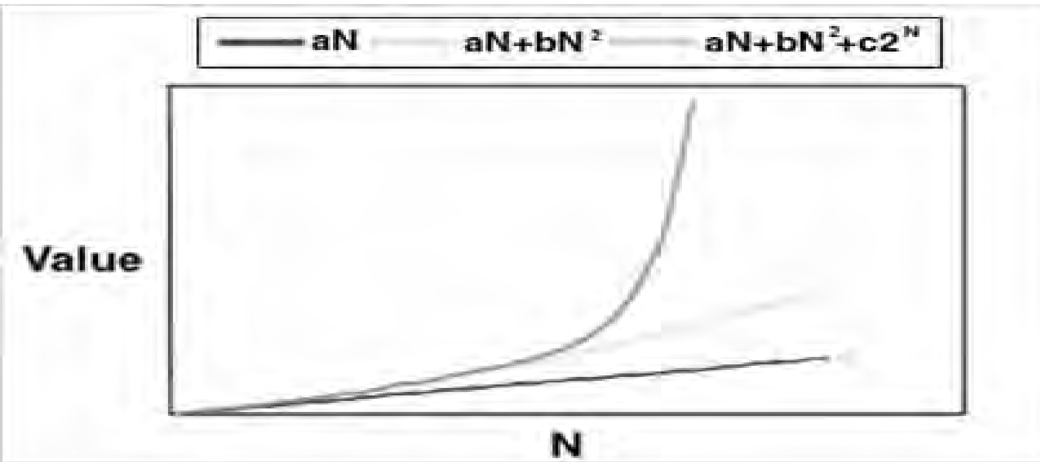
> *This growth rate is faster than the linear growth, of order n, that, according to Sarnoff's Law, governs the value of a broadcast network. On the other hand, it is much slower than the quadratic growth of Metcalfe's Law.*

There is yet no general academic consensus, but even if the previous argument turns out to be true, the total number of possible contacts in a multi-directional network is certainly larger that (*n*), maybe ($n*log(n)$) in many cases, and perhaps as large as (n^2) in some cases. This is obviously more significant for larger numbers. David Reed (2001), a computer scientist at MIT, formulated his own law for groups-forming networks (GFN):

> *[E]ven Metcalfe's Law understates the value created by a group-forming network [GFN] as it grows. Let's say you have a GFN with n members. If you add up all the potential two-person groups, three-person groups, and so on that those members could form, the number of possible groups equals 2^n. So the value of a GFN increases exponentially, in proportion to 2^n. I call that Reed's Law. And its implications are profound.*

Sarnoff's law, Metcalfe's law and Reed's law, even with criticisms such as those by Odlyzko and Tilly, do indeed have profound implications for networks and all their possible and potential combinations: as nodes, connections and groups. Particularly for group-forming networks in multi-directional environments where many types of communications are simultaneously possible. The value of nodes, connections and groups increases with the size of the network, and there are increasing returns and path dependence considerations in such multi-directional new world of fast and cheap telecommunications. Figure 5-1 illustrates the value creation theories according to Sarnoff's law, Metcalfe's law and Reed's law.

Figure 5-1: Networks: nodes, connections and groups



Source: Cordeiro adapted from Reed (2001)

5.3. The Birth of a Global Brain

In the December 1900 issue of *The Ladies Home Journal* there were several predictions for the year 2000. John Elfreth Watkins, an American civil engineer and railroad expert, wrote then an article called "What May Happen in the Next Hundred Years":[45]

> *These prophecies will seem strange, almost impossible. Yet, they have come from the most learned and conservative minds in America. To the wisest and most careful men in our greatest institutions of science and learning I have gone, asking each in his turn to forecast for me what, in his opinion, will have been wrought in his own field of investigation before the dawn of 2001 - a century from now. These opinions I have carefully transcribed.*

Prediction #18, concerning telephones in the year 2000, transcribed the following idea by scientists at that time:

> *Telephones Around the World: Wireless telephone and telegraph circuits will span the world. A husband in the middle of the Atlantic will be able to converse with his wife sitting in her boudoir in Chicago. We will be able to telephone to China quite as readily*

---

[45] During major landmark dates, like a change of century or change of millennium, many people like to ponder about the past and think about the future. Some scientists might do this as well, even if their answers tend not to be very scientific. However, their answers give insights about what "learned" people thought at such times. *The Ladies Home Journal* still exists today, and the 1900 predictions can be seen, for example, here: http://www.yorktownhistory.org/homepages/1900_predictions.htm

as we now talk from New York to Brooklyn. By an automatic signal they will connect with any circuit in their locality without the intervention of a "hello girl".

It is interesting to see what has actually happened in the last 100 years. In fact, this specific prediction was not so much off the mark, even if happened actually earlier than expected by the writer. Now, however, with the continuous growth and the increase of telecommunications, many things will be possible much faster than before.

H. G. Wells, British science fiction writer, proposed the idea of a world encyclopedia, or world brain, and this dream of a universal encyclopedia seems to become a reality today with Wikipedia. Tim Berners-Lee, British computer scientist and co-inventor of the web, was inspired by the free associative possibilities of the brain for his invention. The brain can link different kinds of information without any apparent link otherwise; Lee thought that computers could become much more powerful if they could imitate this functioning, i.e. make links between any arbitrary piece of information. Now, with telecommunications becoming faster, cheaper and better, plus the convergence of telecommunications with other technologies, it might be possible to create a global brain. Alan Turing, often considered to be the father of modern computer science, was interested in artificial intelligence and the possibility for creating computer brains:

No, I'm not interested in developing a powerful brain. All I'm after is just a mediocre brain, something like the President of the American Telephone and Telegraph Company.

Nobel Laureate Robert Fogel, who partially inspired me to write this analysis, expanded his idea of "technophysio evolution" in his book *The Escape from Hunger and Premature Death, 1700–2100: Europe, America, and the Third World*. He refers to technophysio evolution as the relationship between technology (techno) and the human body (physio). He finished his 2004 book with the following premonitory words:

The outlook for new and more effective technologies to deal with chronic disabilities through the marriage of biology and microchip technology is very promising. Indeed, some devices that combine living cells and electronics to replace failed organs are already at the stage of human trials. Somewhat further off, but even more promising, are advances in genetic engineering that will produce cures for what are now untreatable diseases.

The world is changing fast, and thanks to the rapid advances of telecommunications, maybe faster than we expect. As a reputed ancient Chinese proverb and curse says:

May you live in interesting times.

May you come to the attention of those in authority.

May you find what you are looking for

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APPENDIX 1: Chronology of Telecommunications

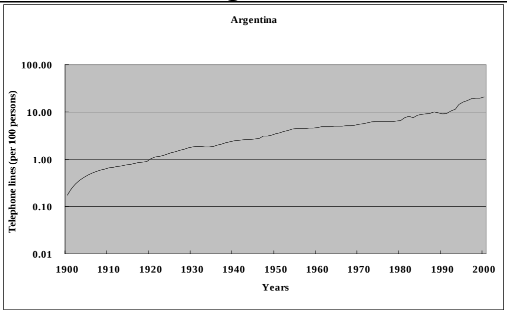
< 3000 BC:	probable use of drums and horns in Africa
< 3000 BC:	probable use of smoke signals and beacons (fires) in few parts of the world
3000 BC:	papyrus is invented in Egypt
2400 BC:	first postal system in Egypt
490 BC:	rudimentary heliographs used by the Greeks and later the Romans
59 BC:	first daily newspaper (*Acta Diurna*) created in Rome by Julius Caesar
100 AD:	paper is invented (refined) by Cai Lun in China
953 AD:	first fountain pen ordered by Al-Muizz Lideenillah in Egypt
1041 AD:	first movable type printing press by Pi Sheng in China
1150 AD:	homing pigeons used in Baghdad
1439 AD:	first alphabetic movable type printing press by Gutenberg in Germany
16th century:	maritime flags used in European costs
1792 AD:	optical telegraph (semaphore lines) invented by Claude Chappe in France
1800s AD:	first typewriters and "typographer" are invented
19th century:	signal lamps used for maritime wars
1837 AD:	first commercial electrical telegraph by Sir William F. Cooke in England
1838 AD:	first electrical telegraph by Samuel Morse in New Jersey
1840 AD:	pre-paid adhesive postage stamps are introduced as standard in England
1849 AD:	first communicating device demonstrated by Antonio Meucci in Havana
1866 AD:	first successful trans-Atlantic telegraph undersea cable
1875 AD:	acoustic telegraphy experiments by Thomas Alva Edison
1876 AD:	first telephone call by Alexander Graham Bell in Boston
1876 AD:	Emperor Pedro II takes the Bell telephone to its second country: Brazil
1885 AD:	American Telephone & Telegraph Company is founded by A.G. Bell
1890 AD:	punched card computing machines used by US Census Bureau
1896 AD:	first radio patent awarded to Guglielmo Marconi in London
1915 AD:	first trans-continental telephone call between NYC and San Francisco
1919 AD:	first commercial radio station in the world opens in the Netherlands
1920 AD:	teleprinter and teletype network begins in the USA and then England
1927 AD:	first public trans-Atlantic phone call (via radio) between NYC and London
1928 AD:	commercial television broadcasts begin (in black and white) in the USA
1935 AD:	first telephone call around the world
1935 AD:	telex network developed in Germany
1947 AD:	transistor is officially born at Bell Labs in the USA
1950 AD:	color television broadcasts begin in the USA
1951 AD:	DDD (Direct Distance Dialing) first offered in the USA

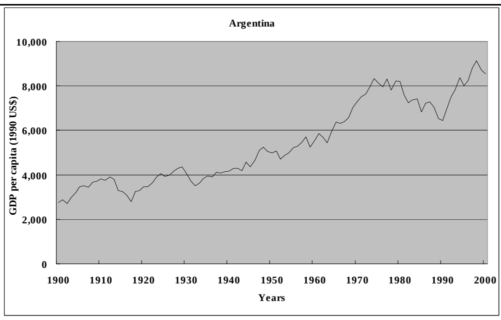
1956 AD:	first trans-Atlantic undersea cable (between Canada and Scotland)
1965 AD:	first geosynchronous communications satellite
1969 AD:	ARPANET starts computer tele-networking
1970 AD:	fiber-optic cable lasers are developed in the USA
1971 AD:	VLSI (very large scale integration) computer chips are developed in USA
1975 AD:	fax machines are mass produced in Japan
1978 AD:	1G (first generation) of mobile telephones is launched in Japan
1980 AD:	IBM launches its PC (personal computer) in the USA
1981 AD:	Minitel starts in France
1982 AD:	CDs (compact discs) are developed in Japan and the Netherlands
1982 AD:	electronic mail was first called e-mail in the USA
1984 AD:	cordless telephone sets are mass produced in Japan
1987 AD:	ADSL (Asymmetric Digital Subscriber Line) is introduced in the USA
1990s AD:	satellite phones become popular in certain markets
1991 AD:	WWW (World Wide Web) is officially born in CERN, Switzerland
1991 AD:	2G GSM (Global System for Mobile) communication starts in Finland
1993 AD:	GPS (global positioning systems) are launched by NAVSTAR in the USA
2000s AD:	satellite Internet becomes legal in many countries
2001 AD:	3G (third generation) of mobile telephones is launched in Japan
2003 AD:	Skype popularizes VoIP (Voice over Internet Protocol) from Estonia
2006 AD:	MoIP (Mobile communications over Internet Protocol) is popular in Korea
2007 AD:	1.3 billion fixed landlines versus 3.3 mobile telephones subscriptions
2008 AD:	WiMAX and other mobile networks spread around the world
2009 AD:	in-flight telephone calls become regular service in some major airlines

APPENDIX 2: Statistical Data (Graphical Form)

Latin America

Argentina





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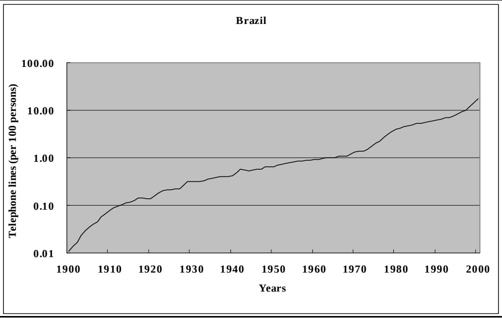
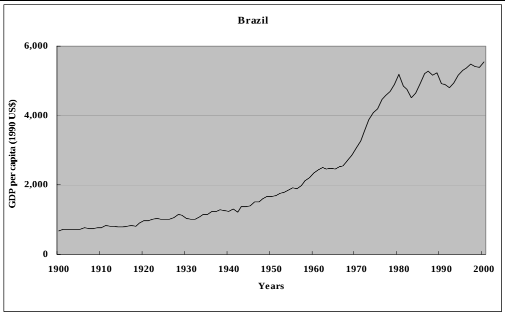
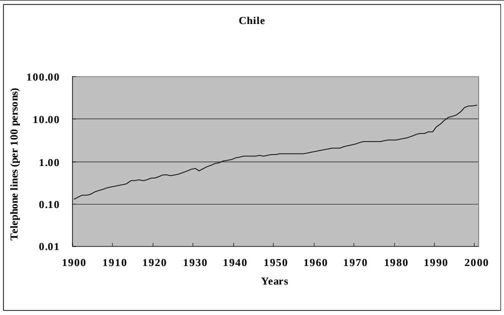
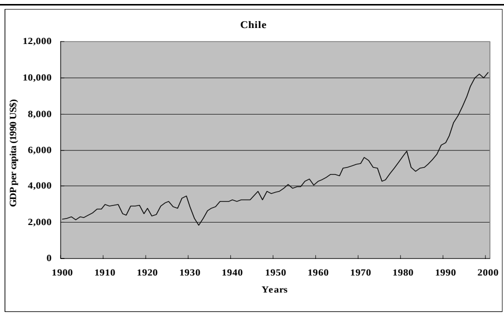




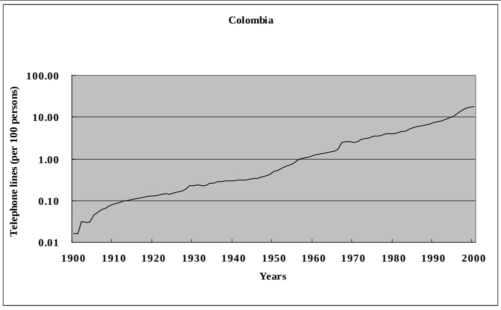
Latin America

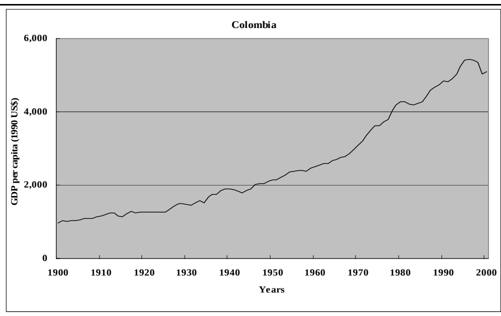
Chile





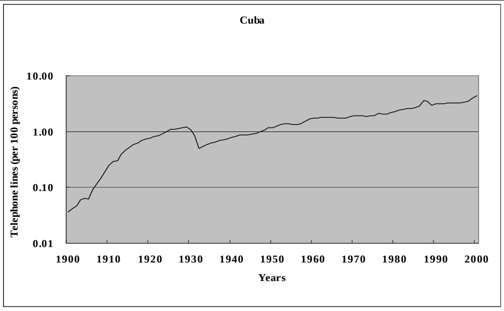
Colombia

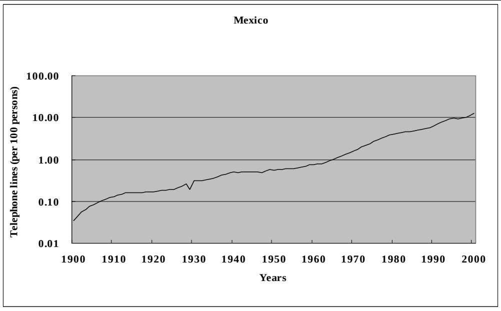


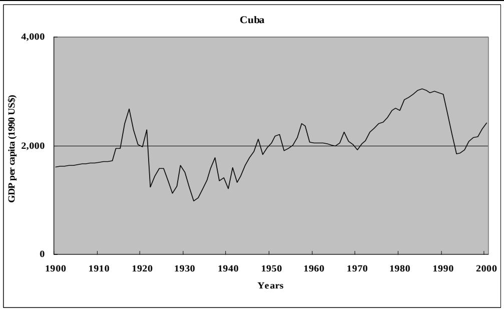


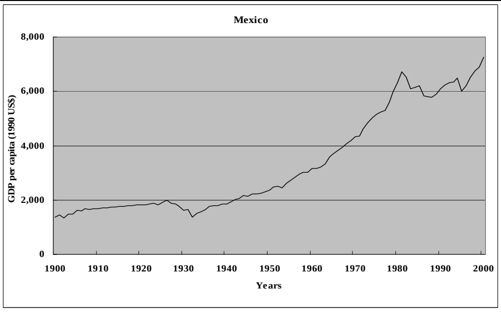
Latin America

Cuba	Mexico



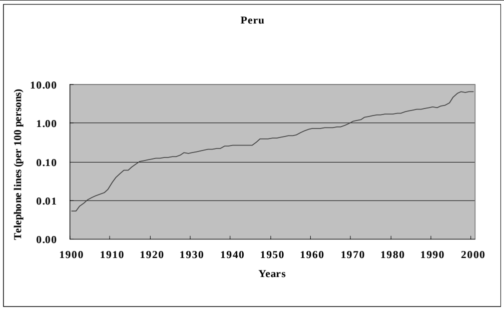


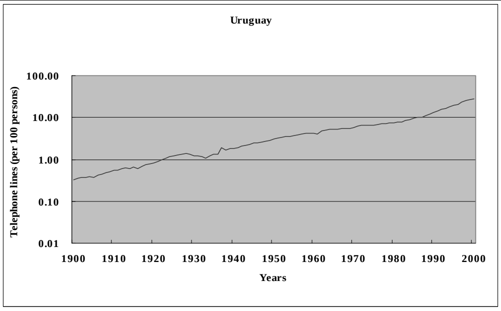


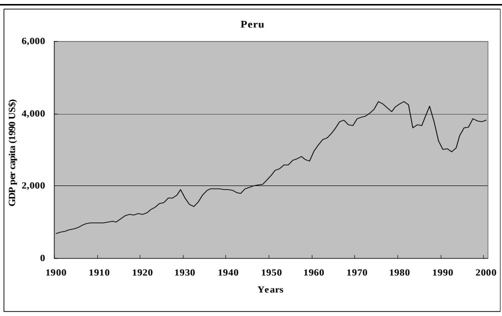


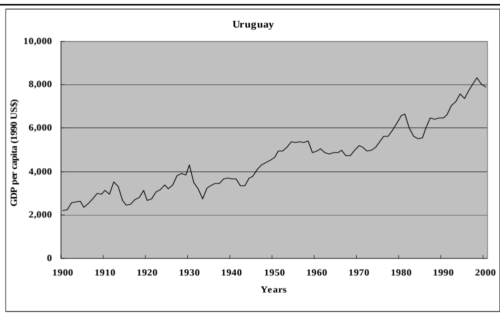
Latin America

Peru	Uruguay



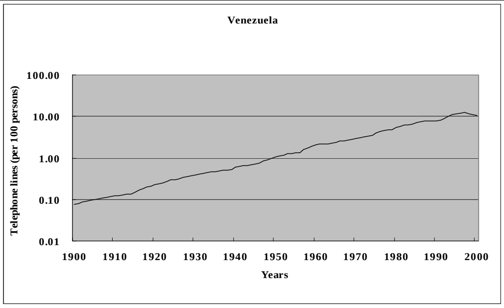


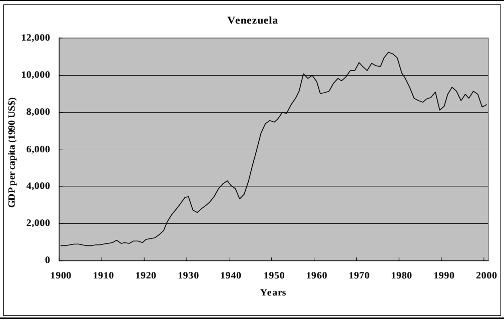




Latin America

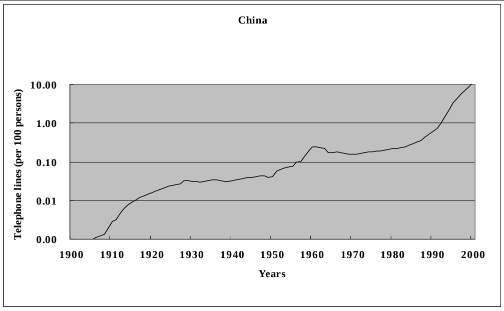
Venezuela

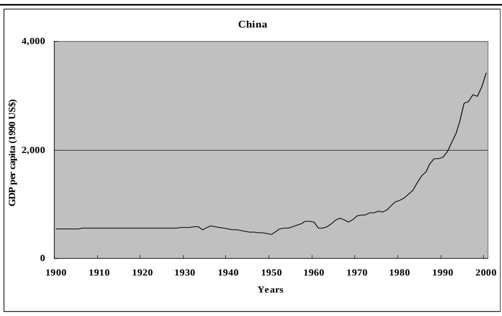




Asia

China





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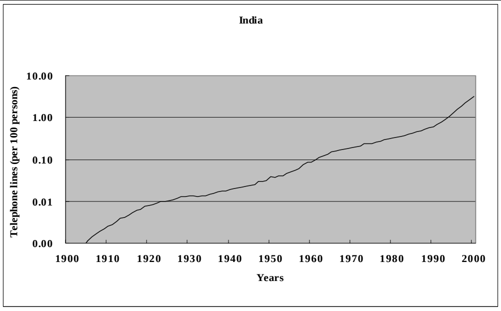

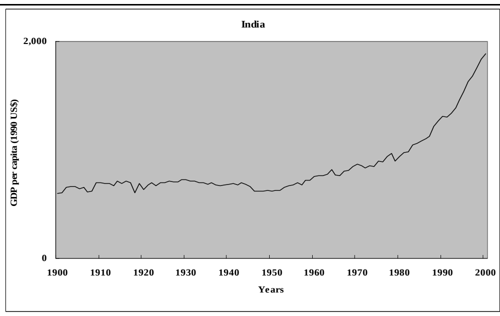

Asia

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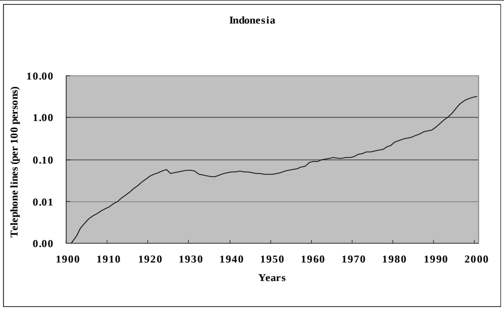	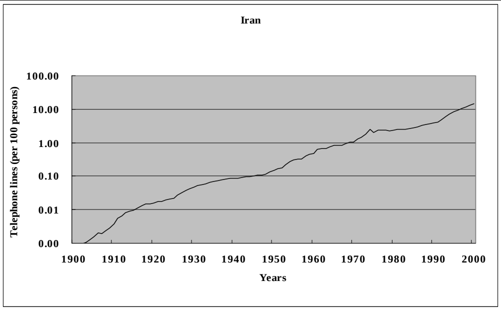
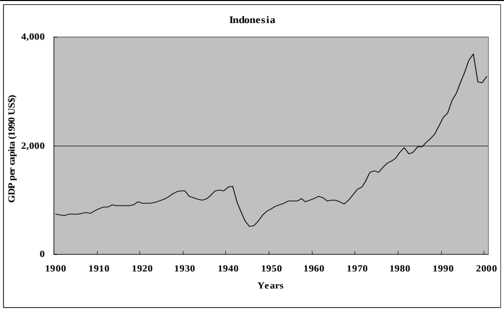	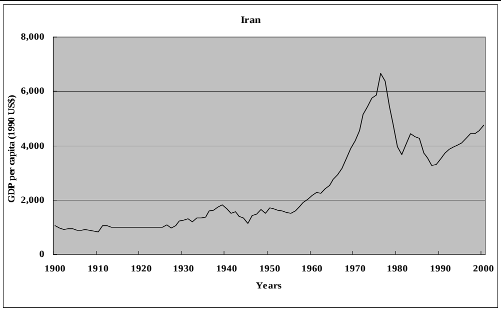

Asia

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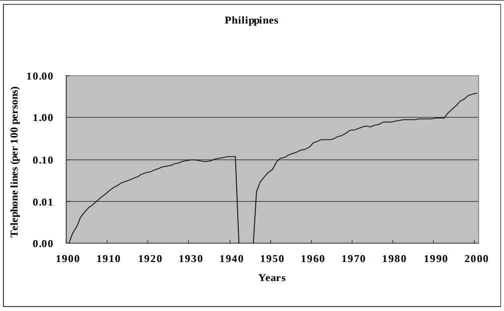
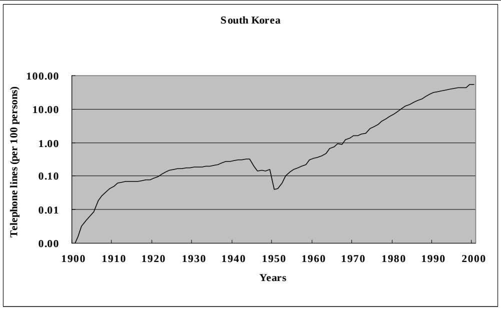
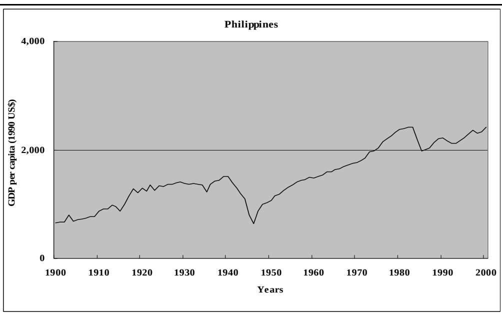
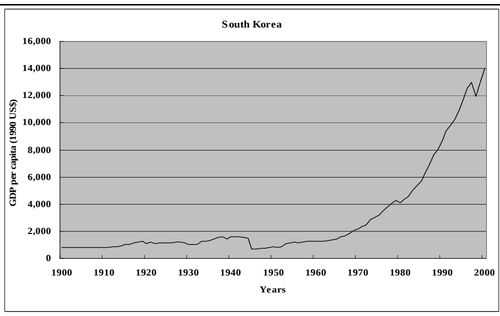
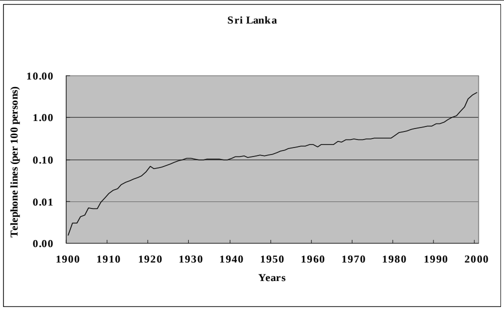
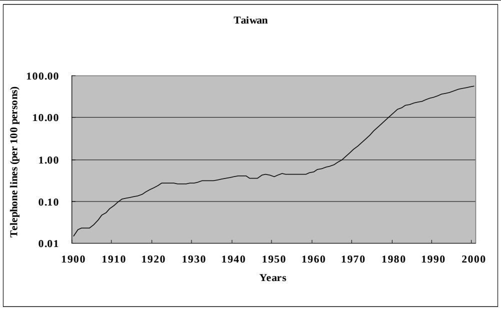
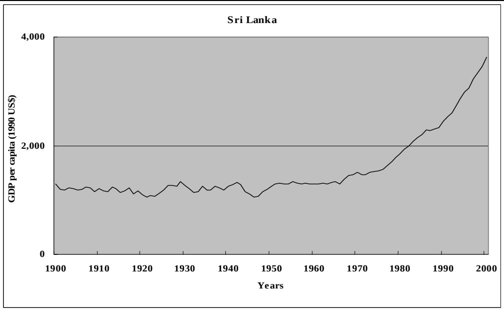
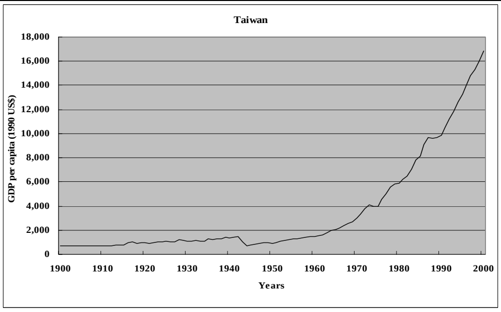
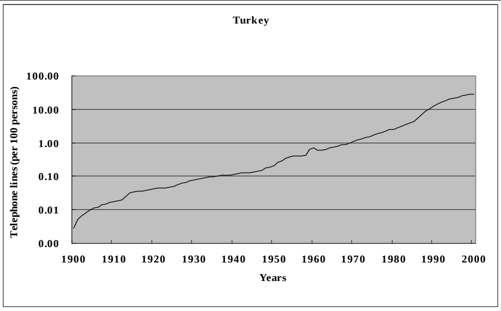
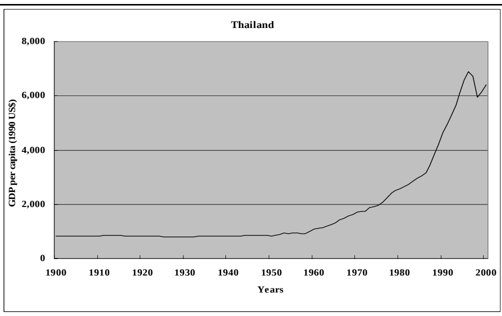
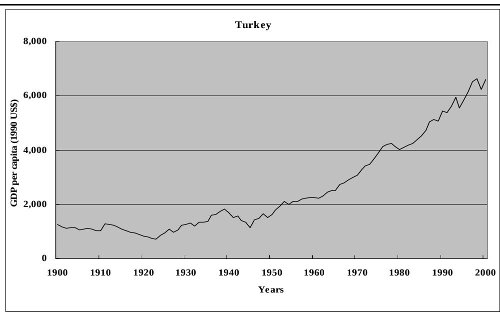
	
	

Asia

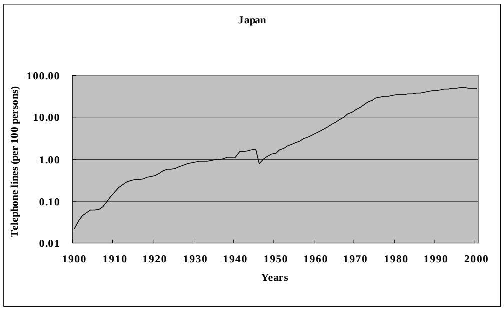
Sri Lanka	Taiwan
	
	

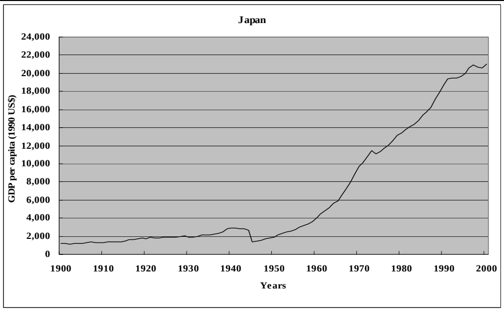
Asia

Thailand	Turkey
	
	

Asia

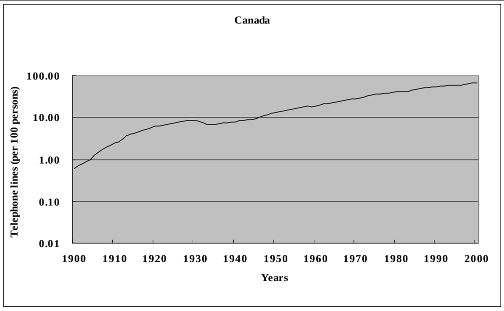
Japan

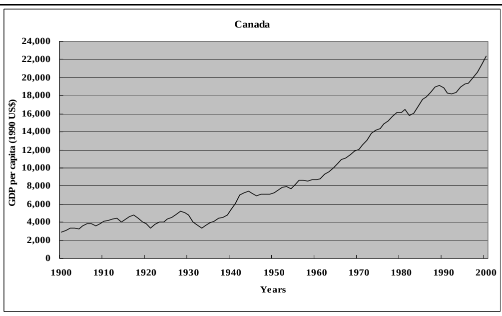




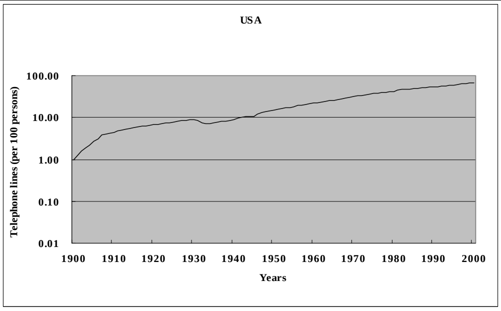
North America

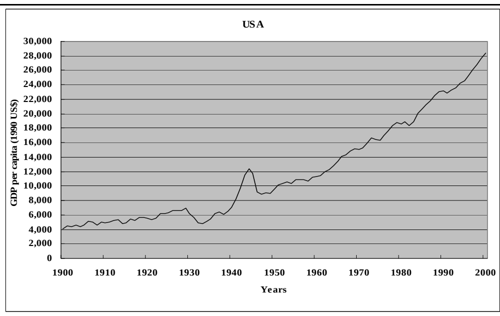
Canada



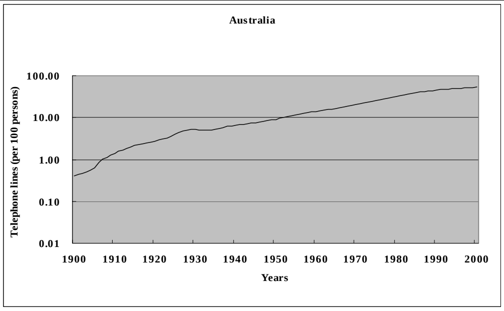
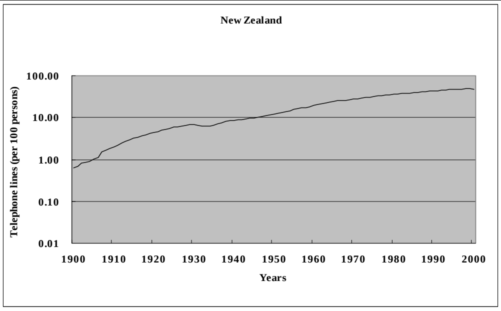
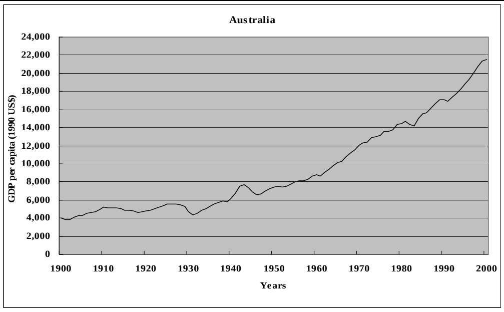
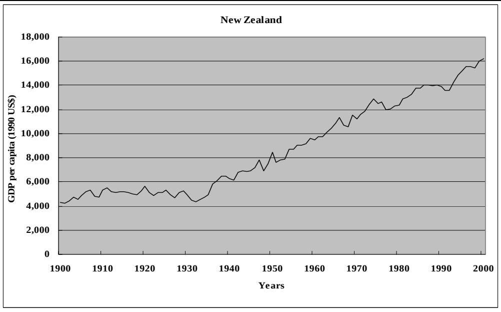


USA

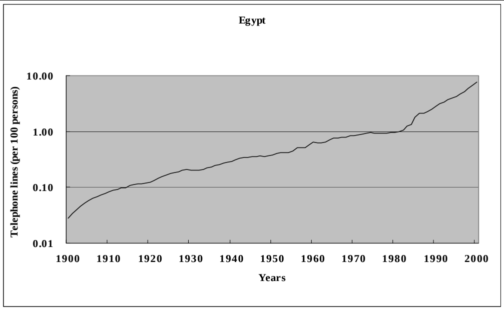
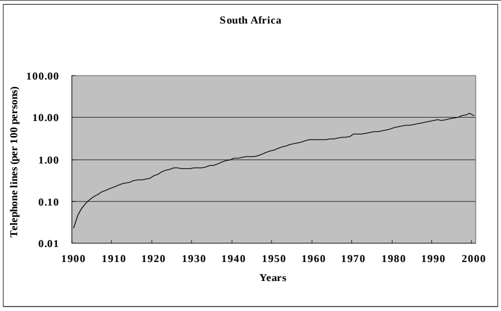
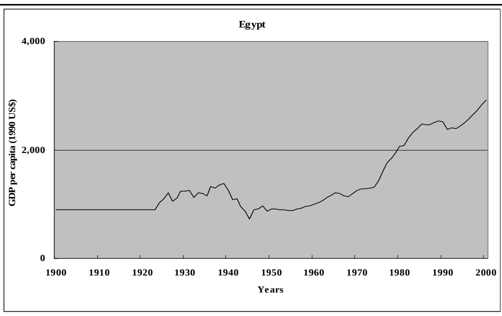
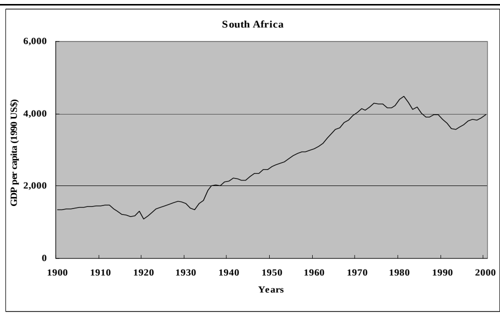




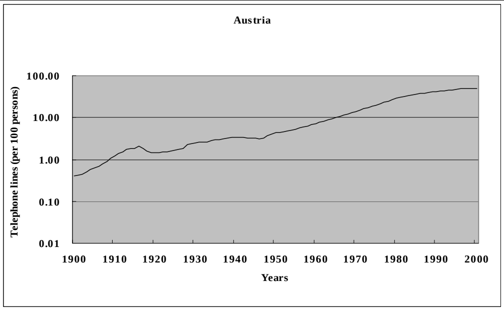
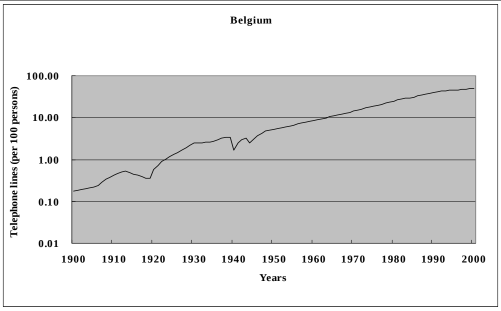
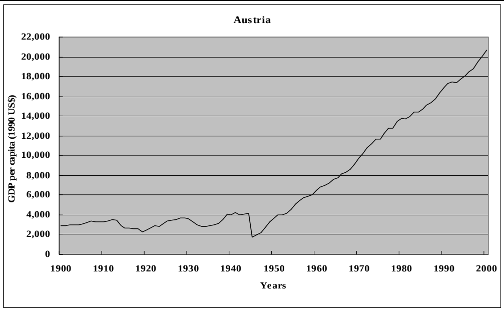
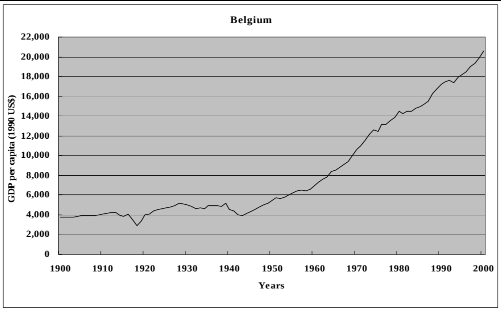
Oceania

Australia	New Zealand
	
	

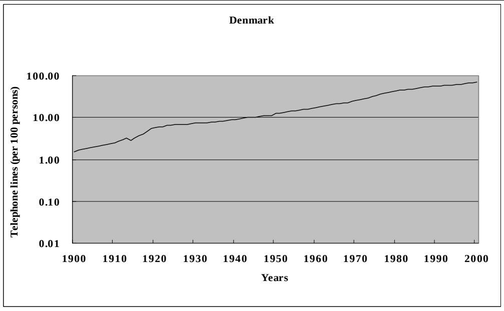
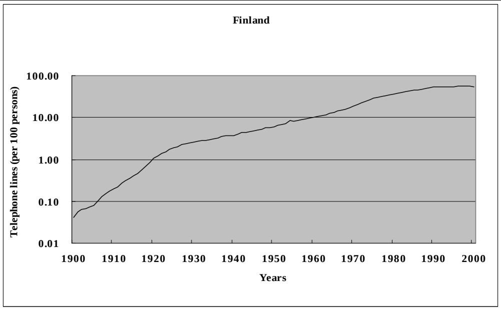
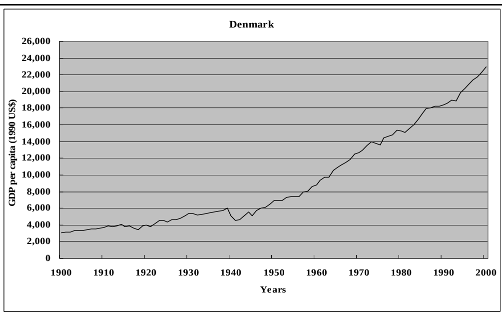
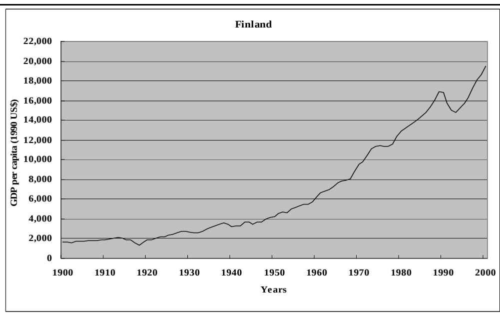
Africa

Egypt	South Africa
	
	

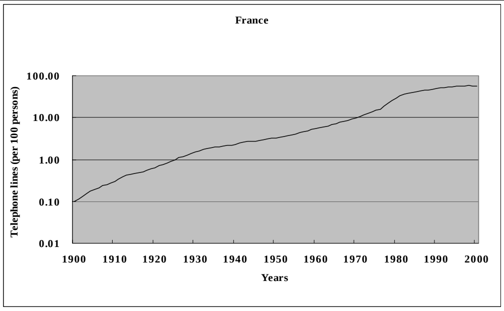
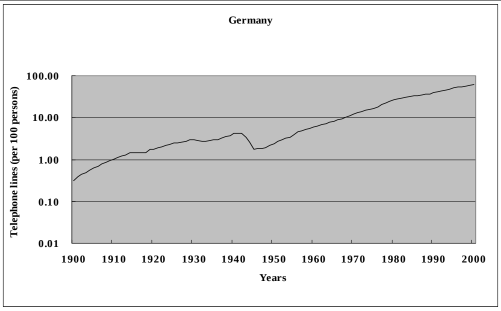
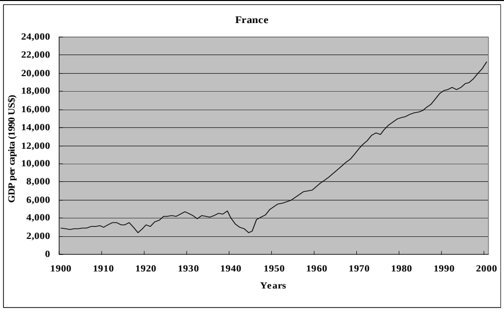
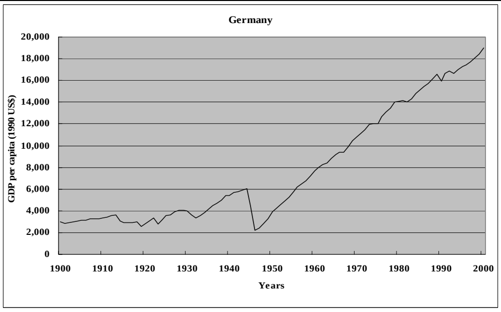
Europe

Austria	Belgium
	
	

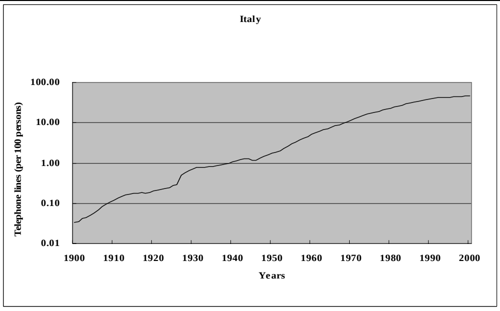
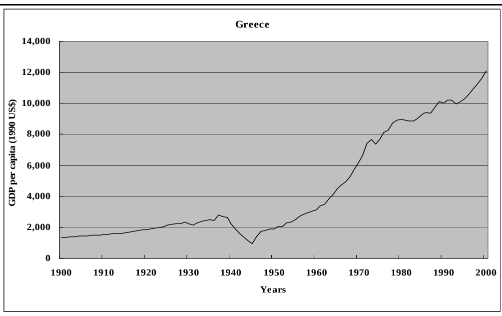
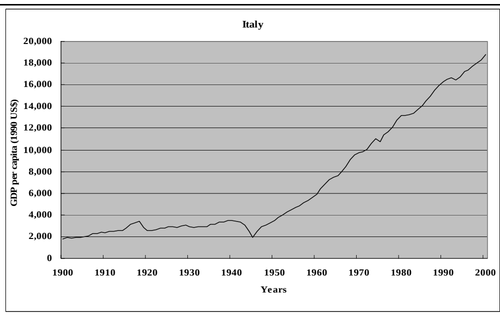
Europe

Denmark	Finland
	
	

Europe

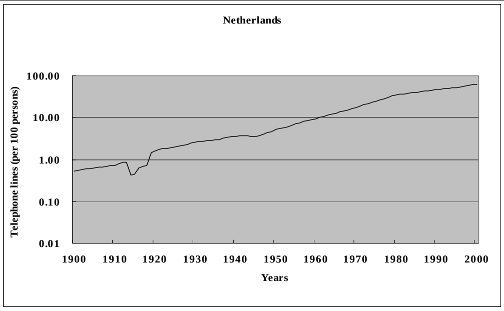
France	Germany
	
	

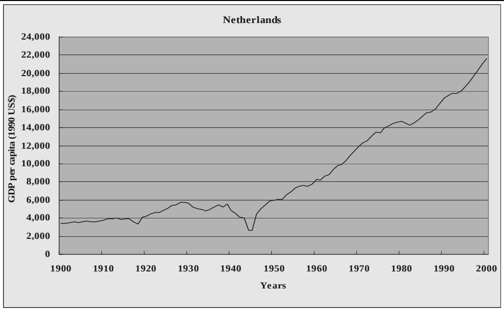
Europe

Greece	Italy
	
	

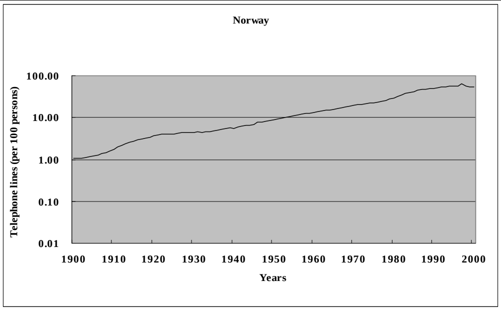
Europe

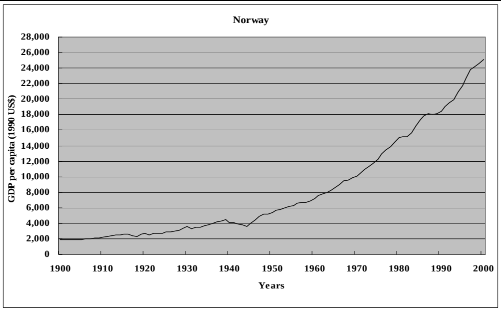
Netherlands





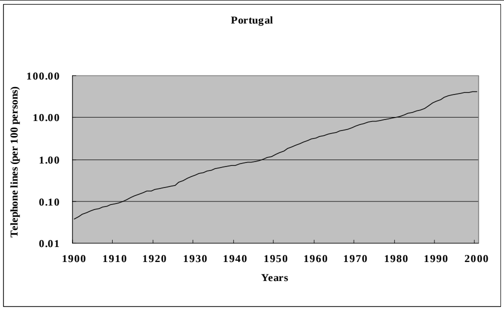
Norway

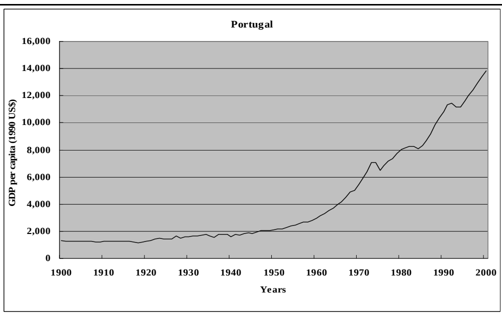




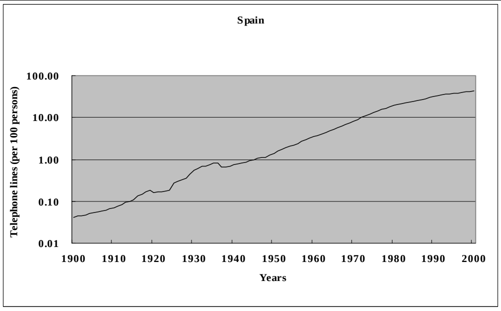
Europe

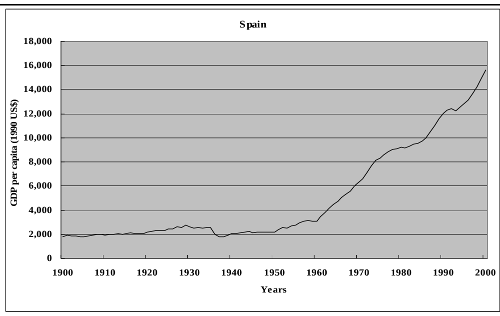
Portugal





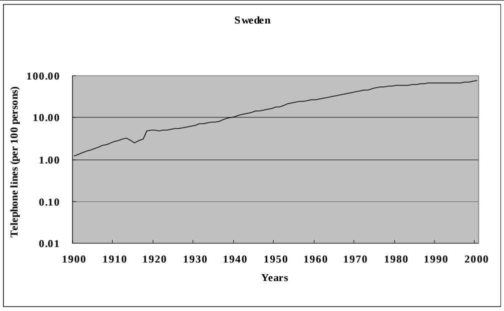
Spain

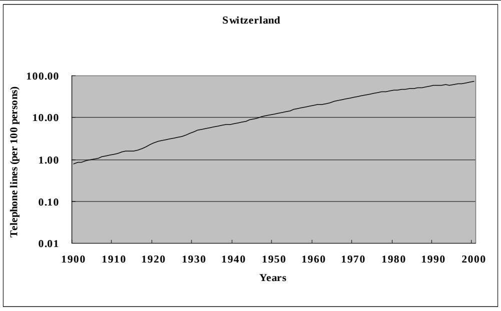


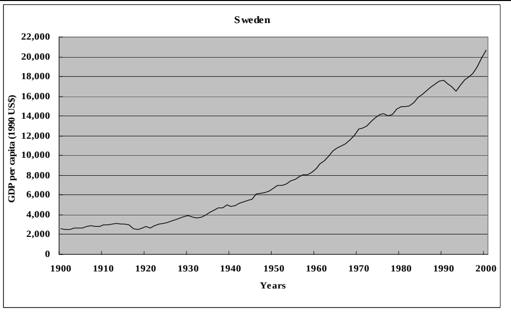


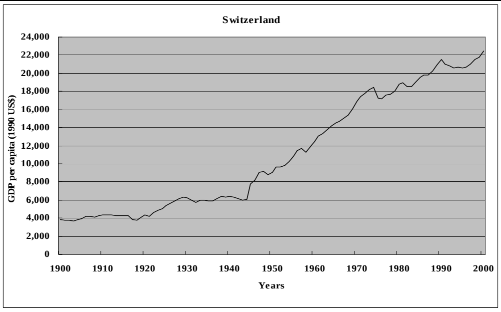
Europe

Sweden	Switzerland



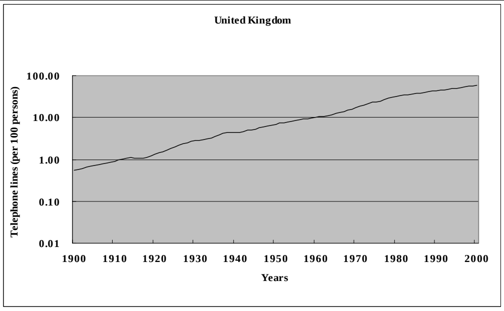


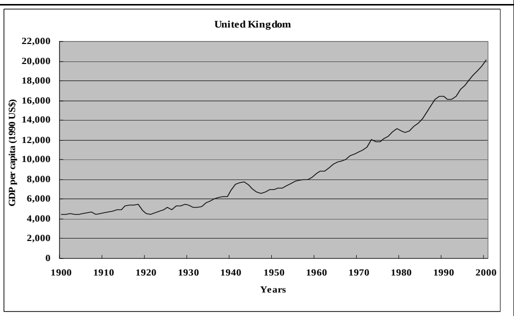




Europe

United Kingdom	





APPENDIX 3: Johansen Cointegration Results

Country	Lag 2				Lag 2		Lag 2			Lag 2	
	Coef. tele Stand. Err	Significan t-statistic	Coef. tren Stand. Err	Significan t-statistic	# Cointegrating vect Trace	 Max-Eig	Coef. tele Stand. Err	Significan t-statistic	NO trend	# Cointegrating vec Trace	 Max-Eig
Latin America											
Argentina	0.51951 (0.1509)	−3.44	−0.02909 (0.0053)	5.47	0	0	−0.30423 (0.0628)	4.84		0	0
Brazil	−16.8604 (5.0928)	3.31	0.879294 (0.2794)	−3.15	0	0	−0.46841 (0.0346)	13.54		0	0
Chile	−0.16723 (0.1655)	1.01	−0.006 (0.0067)	0.89	0	0	−0.3111 (0.0323)	9.63		0	0
Colombia	−0.09748 (0.1042)	0.94	−0.01242 (0.0063)	1.97	0	0	−0.3013 (0.0171)	17.64		0	0
Cuba	−0.45996 (0.1312)	3.51	0.002529 (0.0044)	−0.57	1	1	−0.367 (0.0592)	6.20		1	1
Mexico	−0.41789 (0.2766)	1.51	0.003767 (0.0140)	−0.27	0	0	−0.3455 (0.0432)	7.99		0	0
Peru	0.615113 (0.2132)	−2.89	−0.04601 (0.0120)	3.84	0	0	−0.1335 (0.0753)	1.77		0	0
Uruguay	−0.11859 (0.1313)	0.90	−0.01328 (0.0104)	1.28	0	0	−0.28322 (0.0214)	13.27		0	0
Venezuela	−11.0582 (3.7108)	2.98	0.547959 (0.1965)	−2.79	0	0	−1.24846 (0.3978)	3.14		0	0
Asia											
China	−0.352 (0.2049)	1.72	0.030032 (0.0154)	−1.96	0	0	−0.05528 (0.0465)	1.19		2	2
India	−0.26199 (0.1667)	1.57	0.017913 (0.0119)	−1.51	1	1	0.061686 (0.0410)	−1.50		2	2
Indonesia	−0.36406 (0.0791)	4.60	0.005602 (0.0043)	−1.30	0	0	−0.26946 (0.0303)	8.91		0	0
Iran	8.699969 (2.1938)	−3.97	−0.74238 (0.1937)	3.83	0	0	−0.28238 (0.0410)	6.89		0	0
Philippines	−0.18458 (0.0168)	10.99	−0.00016 (0.0011)	0.14	1	1	−0.18694 (0.0090)	20.77		1	1
South Korea	−0.50476 (0.0625)	8.08	0.010924 (0.0053)	−2.07	0	1	−0.39833 (0.0292)	13.64		1	1
Sri Lanka	−0.1332 (0.0670)	1.99	−0.0054 (0.0033)	1.63	1	1	−0.23174 (0.0280)	8.29		2	2
Taiwan	−0.54223 (0.0834)	6.50	0.00424 (0.0063)	−0.68	0	0	−0.49456 (0.0287)	17.21		1	1
Thailand	−0.63162 (0.0721)	8.76	0.028903 (0.0060)	−4.83	1	1	−0.37772 (0.0414)	9.12		1	1
Turkey	−0.11859 (0.1313)	0.90	−0.01328 (0.0104)	1.28	0	0	−0.28322 (0.0214)	13.27		0	0
Japan	−1.12929 (0.2348)	4.81	0.036713 (0.0172)	−2.14	1	1	−0.60955 (0.0441)	13.81		1	1
North America											
Canada	−0.29737 (0.0612)	4.86	−0.01377 (0.0025)	5.62	2	2	−0.70394 (0.0334)	21.08		1	1
USA	−0.43717 (0.0897)	4.87	−0.00707 (0.0029)	2.43	2	2	−0.65962 (0.0220)	30.02		1	1
Oceania											
Australia	−3.92517 (0.8458)	4.64	0.120361 (0.0358)	−3.36	2	2	−0.58865 (0.0404)	14.56		1	1
New Zealand	−0.0826 (0.0703)	1.18	−0.01612 (0.0026)	6.13	1	1	−0.62862 (0.0512)	12.29		1	1
Africa											
Egypt	−0.35842 (0.2888)	1.24	0.006882 (0.0127)	−0.54	0	0	−0.21263 (0.0427)	4.98		1	0
South Africa	−2.90723 (0.7771)	3.74	0.106171 (0.0345)	−3.08	0	0	−0.45745 (0.0566)	8.08		0	0
Europe											
Austria	−1.1757 (0.3108)	3.78	0.028861 (0.0149)	−1.94	0	0	−0.57536 (0.0494)	11.66		0	1
Belgium	0.522227 (0.3509)	−1.49	−0.05953 (0.0207)	2.87	1	0	−1.14041 (0.2217)	5.14		0	1
Denmark	−1.25802 (0.6242)	2.02	0.021618 (0.0234)	−0.92	0	0	−0.64662 (0.0576)	11.24		0	0
Finland	−0.20123 (0.1545)	1.30	−0.02713 (0.0099)	2.75	0	0	−0.96739 (0.1510)	6.41		1	1
France	0.109476 (0.2911)	−0.38	−0.03369 (0.0180)	1.87	0	0	−0.46389 (0.0496)	9.36		0	0
Germany	−0.18585 (0.0901)	2.06	−0.01497 (0.0043)	3.46	1	1	−0.50372 (0.0279)	18.03		1	1
Greece	1.3606 (0.7443)	−1.83	−0.14947 (0.0681)	2.20	0	0	−0.34929 (0.0698)	5.00		0	0
Italy	2.706985 (1.8813)	−1.44	−0.20578 (0.1432)	1.44	0	0	−0.58793 (0.1384)	4.25		0	0
Netherlands	−3.00762 (0.9087)	3.31	0.135109 (0.0472)	−2.86	0	0	−0.41205 (0.0488)	8.45		0	0
Norway	−2.74574 (0.4483)	6.12	0.078034 (0.0181)	−4.32	1	1	−0.74027 (0.0240)	30.87		1	1
Portugal	8.337801 (2.2568)	−3.69	−0.59423 (0.1567)	3.79	0	0	−0.60637 (0.0793)	7.65		0	0
Spain	3.913625 (1.9694)	−1.99	−0.33913 (0.1491)	2.28	0	0	−0.98676 (0.2830)	3.49		0	0
Sweden	−0.57277 (0.3329)	1.72	−0.00486 (0.0145)	0.33	0	0	−0.69933 (0.0573)	12.21		0	0
Switzerland	−0.473 (0.3425)	1.38	−0.00532 (0.0167)	0.32	0	0	−0.59249 (0.0513)	11.54		2	0
United Kingdom	0.415959 (0.3117)	−1.33	−0.03613 (0.0152)	2.37	0	0	−0.35749 (0.0304)	11.75		0	0

Shadowed boxes indicate significant result (t statistics)

Country	Lag 4			Significanc	Lag 4		Lag 4			Lag 4	
	Coef. tele Stand. Er	Significanc t-statistic	Coef. tre Stand. Er	t-statistic	# Cointegrating vec Trace	Max-Eig	Coef. tele Stand. Er	Significanc t-statistic	NO trend	# Cointegrating vec Trace	Max-Eig
Latin America											
Argentina	0.46499 (0.1257)	-3.70	-0.0271 (0.0044)	6.19	0	1	-0.3235 (0.0545)	5.94		0	0
Brazil	1.13621 (0.3701)	-3.07	-0.0855 (0.0199)	4.30	0	0	-0.4617 (0.0496)	9.31		0	0
Chile	-0.1087 (0.2124)	0.51	-0.0088 (0.0084)	1.05	0	0	-0.3282 (0.0415)	7.90		0	0
Colombia	-0.3621 (0.1275)	2.84	0.00329 (0.0077)	-0.43	0	0	-0.3076 (0.0127)	24.32		0	0
Cuba	-0.8055 (0.1852)	4.35	0.01108 (0.0058)	-1.90	1	1	-0.3868 (0.0595)	6.50		1	1
Mexico	3.79214 (1.6086)	-2.36	-0.2319 (0.0815)	2.85	0	0	-0.3304 (0.0454)	7.27		0	0
Peru	0.73351 (0.2218)	-3.31	-0.0515 (0.0122)	4.23	0	0	0.00679 (0.1216)	-0.06		0	0
Uruguay	-0.0487 (0.1433)	0.34	-0.0191 (0.0113)	1.70	0	0	-0.2868 (0.0248)	11.56		0	0
Venezuela	-11.268 (4.8752)	2.31	0.55535 (0.2583)	-2.15	0	0	-3.8913 (1.6727)	2.33		0	0
Asia											
China	-0.6911 (0.3546)	1.95	0.07359 (0.0267)	-2.75	1	0	0.02694 (0.0686)	-0.39		2	0
India	0.06947 (0.4219)	-0.16	0.01111 (0.0293)	-0.38	1	1	0.2863 (0.0802)	-3.57		1	1
Indonesia	-0.3763 (0.1013)	3.71	0.00691 (0.0054)	-1.29	0	0	-0.2625 (0.0399)	6.58		0	0
Iran	9.58721 (1.9863)	-4.83	-0.8177 (0.1721)	4.75	1	1	-0.2791 (0.0393)	7.10		0	0
Philippines	-0.3061 (0.0502)	6.10	0.007 (0.0032)	-2.17	0	0	-0.1897 (0.0140)	13.56		0	0
South Korea	-0.5198 (0.0495)	10.51	0.01331 (0.0041)	-3.22	0	1	-0.391 (0.0287)	13.65		0	1
Sri Lanka	-0.1523 (0.0884)	1.72	-0.0008 (0.0041)	0.19	0	0	-0.163 (0.0357)	4.57		2	0
Taiwan	-0.6097 (0.0450)	13.54	0.01123 (0.0034)	-3.31	1	1	-0.4817 (0.0186)	25.97		1	1
Thailand	-0.6402 (0.1009)	6.34	0.02963 (0.0078)	-3.78	0	0	-0.3995 (0.0765)	5.22		0	0
Turkey	-0.0487 (0.1433)	0.34	-0.0191 (0.0113)	1.70	0	0	-0.2868 (0.0248)	11.56		0	0
Japan	-1.092 (0.2475)	4.41	0.03373 (0.0178)	-1.89	0	1	-0.6091 (0.0486)	12.53		1	1
North America											
Canada	-0.3367 (0.0695)	4.84	-0.0123 (0.0028)	4.36	2	2	-0.6932 (0.0356)	19.48		1	1
USA	-0.4943 (0.0919)	5.38	-0.0054 (0.0030)	1.79	1	1	-0.6638 (0.0232)	28.59		1	1
Oceania											
Australia	-4.1495 (0.7782)	5.33	0.13022 (0.0314)	-4.14	2	2	-0.5787 (0.0330)	17.55		1	1
New Zealand	-0.1933 (0.0483)	4.00	-0.0124 (0.0018)	7.07	1	1	-0.5907 (0.0289)	20.47		1	1
Africa											
Egypt	-0.5667 (0.3723)	1.52	0.01851 (0.0162)	-1.14	0	0	-0.1655 (0.0486)	3.40		1	0
South Africa	-2.5535 (0.8660)	2.95	0.0905 (0.0382)	-2.37	0	0	-0.4789 (0.0673)	7.12		0	0
Europe											
Austria	-1.6755 (0.4010)	4.18	0.05275 (0.0193)	-2.73	0	0	-0.5911 (0.0574)	10.30		0	0
Belgium	0.81647 (0.2126)	-3.84	-0.0709 (0.0128)	5.55	1	1	-1.21 (0.2665)	4.54		0	0
Denmark	-1.0948 (0.5476)	2.00	0.01713 (0.0207)	-0.83	0	0	-0.6256 (0.0554)	11.30		0	0
Finland	-0.3684 (0.1493)	2.47	-0.0165 (0.0092)	1.80	0	1	-0.7377 (0.0845)	8.73		1	1
France	0.14556 (0.2227)	-0.65	-0.035 (0.0139)	2.53	0	0	-0.446 (0.0412)	10.82		0	0
Germany	-0.2236 (0.0816)	2.74	-0.0135 (0.0040)	3.41	1	1	-0.5107 (0.0290)	17.61		1	1
Greece	1.94266 (0.9339)	-2.08	-0.2011 (0.0858)	2.34	0	0	-0.349 (0.0756)	4.62		0	0
Italy	2.54885 (1.2618)	-2.02	-0.2044 (0.0966)	2.12	0	0	-0.7622 (0.2237)	3.41		0	0
Netherlands	-4.2103 (0.9701)	4.34	0.19903 (0.0504)	-3.95	0	0	-0.4099 (0.0481)	8.52		0	0
Norway	-0.1647 (0.2649)	0.62	-0.0239 (0.0106)	2.27	0	0	-0.8198 (0.0533)	15.38		0	0
Portugal	19.7468 (4.8991)	-4.03	-1.3536 (0.3397)	3.99	1	1	-0.593 (0.0697)	8.50		0	0
Spain	7.01695 (2.3650)	-2.97	-0.5687 (0.1801)	3.16	0	0	-1.3389 (0.4361)	3.07		0	0
Sweden	-0.141 (0.2155)	0.65	-0.0249 (0.0095)	2.62	1	1	-0.8621 (0.0741)	11.63		1	1
Switzerland	-0.4654 (0.3903)	1.19	-0.0081 (0.0192)	0.42	0	0	-0.6547 (0.0669)	9.79		2	2
United Kingdom	0.47607 (0.3775)	-1.26	-0.0411 (0.0185)	2.22	0	0	-0.4202 (0.0417)	10.08		0	0

Shadowed boxes indicate significant result (t statistics)

APPENDIX 4: Granger Causality Results

Country	Lag 1 VEC		Lag 2 VEC		Lag 3 VEC		Lag 4 VEC		Lag AIC	Lag SIC	Lag 2 VAR	Lag 3 VAR
	No Granger causality		No Granger causality		No Granger causality		No Granger causality		No trenc	No trenc	No Granger causality	
	TEL > GDI	Probability	TEL > GDI	Probability	TEL > GDI	Probability	TEL > GDI	Probability	Constan	Constan	TEL > GDP	TEL > GDP
Latin America	GDP > TE	Probability	GDP > TE	Probability	GDP > TE	Probability	GDP > TE	Probability			GDP > TEL	GDP > TEL
Argentina	2.11376	0.14921	1.6454	0.19844	1.94917	0.12726	1.31416	0.27097	2	2	0.1929	
	5.59394	0.02001	1.3298	0.26946	1.80427	0.15198	1.47675	0.21607			0.2645	
Brazil	0.00974	0.92159	1.73416	0.18215	0.99518	0.39883	0.89305	0.47166	2	2	0.1765	
	38.66	1.30E-08	4.21069	0.01773	3.57194	0.01705	1.79675	0.13662			0.0148	
Chile	8.77483	0.00384	9.12664	0.00024	5.32519	0.002	3.4606	0.01128	3	2	0.0001	0.0011
	2.60605	0.10971	1.07038	0.34702	0.71806	0.54372	0.77947	0.54149			0.3429	0.541
Colombia	0.8012	0.37295	2.13018	0.12452	1.09053	0.35727	0.8755	0.48203	2	1	0.1188	
	14.9404	2.00E-04	11.1603	4.50E-05	1.64151	0.1853	2.41813	0.05448			0.000001	
Cuba	0.83338	0.36356	1.98287	0.14339	1.30164	0.27878	0.76727	0.54936	2	1	0.1377	
	8.97084	0.00348	1.97172	0.14493	2.01473	0.1174	2.25382	0.06964			0.1392	
Mexico	0.41292	0.52201	1.03908	0.35781	3.4846	0.019	9.83821	1.30E-06	5	4	0.3538	0.0151
	11.1905	0.00117	4.82862	0.01009	2.54297	0.06111	1.4947	0.21068			0.008	0.0543
Peru	0.58704	0.44543	1.38869	0.25447	1.07672	0.36304	0.68638	0.60327	2	2	0.2494	
	0.28162	0.59686	0.13972	0.86979	0.42001	0.73908	0.73646	0.56956			0.8696	
Uruguay	7.20538	0.00855	2.97983	0.05562	2.19553	0.09395	1.64377	0.1704	2	1	0.000001	
	33.2707	9.60E-08	3.38284	0.03813	3.10332	0.03048	2.07577	0.09073			0.1771	
Venezuela	1.1706	0.28196	0.14309	0.86687	0.15387	0.92695	0.1743	0.95104	2	2	0.8667	
	3.44108	0.06663	1.21863	0.30026	0.8413	0.47473	0.61089	0.65587			0.2956	
Asia												
China	0.81871	0.3678	1.37907	0.25686	1.36634	0.25811	1.02874	0.39702	3	2	0.2518	0.251
	59.6368	1.00E-11	6.62343	0.00204	3.98066	0.0103	3.14472	0.0182			0.0013	0.0076
India	0.50405	0.47943	0.11786	0.88895	1.44947	0.23366	1.66487	0.16532	5	1	0.8888	0.2262
	22.3643	7.70E-06	15.2431	1.80E-06	2.93412	0.03761	2.48859	0.04901			0.000001	0.032
Indonesia	0.54756	0.4611	2.32746	0.10314	1.25913	0.29318	1.1098	0.35706	2	2	0.0975	
	69.2359	5.60E-13	5.94826	0.00369	2.82392	0.04312	2.30151	0.06486			0.0026	
Iran	6.38252	0.01314	2.82133	0.06458	2.27669	0.08498	2.33559	0.06164	3	1	0.0595	0.0775
	0.00149	0.96929	0.05732	0.94432	0.44124	0.72407	0.30005	0.87718			0.9443	0.7235
Philippines	64.0785	2.60E-12	29.8244	9.30E-11	22.367	6.20E-11	21.5434	2.00E-12	8	1	0.000001	0.000001
	0.02814	0.86712	0.62182	0.53916	1.18055	0.32162	1.83748	0.12876			0.537	0.3154
South Korea	1.8177	0.18073	2.56396	0.08238	1.7669	0.15907	1.77842	0.14031	6	6	0.077	0.1511
	23.7089	4.40E-06	5.35486	6.28E-03	2.45549	6.81E-02	1.839	1.28E-01			0.0047	0.0611
Sri Lanka	3.51084	0.06398	0.79169	0.45608	1.35845	0.26055	0.90951	0.46209	1	1	0.4531	0.2534
	50.5052	2.00E-10	19.1679	1.00E-07	8.25558	6.50E-05	6.86788	7.40E-05			0.000001	0.000001
Taiwan	1.75845	0.18793	2.36152	0.09985	1.21532	0.30873	0.99401	0.4152	6	2	0.0943	0.3023
	25.7414	1.90E-06	1.07156	0.34662	2.14901	0.0995	3.29162	0.01457			0.3425	0.0918
Thailand	9.98991	0.0021	5.01842	0.0085	3.75208	0.01365	3.57361	0.00951	6	2	0.0066	0.0104
	4.06173	0.04663	3.05483	0.05184	1.97089	0.12391	1.04251	0.39			0.0471	0.1159
Turkey	7.20538	0.00855	2.97983	0.05562	2.19553	0.09395	1.64377	0.1704	3	1	0.0508	0.0863
	33.2707	9.60E-08	3.38284	0.03813	3.10332	0.03048	2.07577	0.09073			0.034	0.0254
Japan	1.94039	0.16678	1.35153	0.26372	0.88499	0.45191	0.79155	0.53361	7	2	0.2588	0.4479
	16.9483	8.00E-05	64.2463	2.00E-18	44.5965	5.20E-18	33.1994	4.00E-17			0.000001	0.000001
North America												
Canada	0.20356	0.65286	0.23062	0.79448	0.81741	0.48741	0.83536	0.50615	8	2	0.794	0.484
	57.9368	1.70E-11	15.6005	1.40E-06	12.5132	5.90E-07	9.13247	2.90E-06			0.000001	0.000001
USA	0.41123	0.52284	2.11781	0.12588	3.11583	0.02985	2.36034	0.05903	3	2	0.1203	0.025
	129.166	1.40E-19	7.75527	0.00075	5.38059	0.00184	4.71356	0.00166			0.0004	0.0011
Oceania												
Australia	0.05879	0.80894	1.09183	0.33982	0.32948	0.80404	0.42046	0.79348	3	2	0.3356	0.8041
	24.5131	3.10E-06	7.61446	0.00086	6.52458	0.00048	5.69121	0.0004			0.0005	0.0002
New Zealand	0.87907	0.35078	0.70519	0.49661	0.5898	0.62324	0.48322	0.74798	3	1	0.494	0.6216
	24.6068	3.00E-06	8.72881	0.00033	6.02128	0.00087	5.90247	0.0003			0.0002	0.0004
Africa												
Egypt	0.02552	0.87341	0.74682	0.47666	1.28414	0.28462	1.02737	0.39773	2	2	0.4739	
	29.2451	4.60E-07	5.81824	0.00415	3.72998	0.01403	2.22233	0.07299			0.003	
South Africa	1.38806	0.24161	1.95759	0.14691	1.53855	0.2099	1.10352	0.36004	2	2	0.1412	
	46.6247	7.50E-10	5.05755	0.0082	3.19288	0.02728	2.66745	0.03745			0.0064	
Europe												
Austria	3.19135	0.07712	3.43165	0.03635	2.26399	0.08609	2.00422	0.10041	2	2	0.0323	
	18.1053	4.80E-05	2.69431	0.0727	2.19007	0.09434	1.62145	0.1755			0.0676	
Belgium	1.85982	0.17577	0.91766	0.40293	2.96395	0.03606	2.02282	0.09768	3	1	0.3995	0.0308
	0.06328	0.80191	1.77841	0.17443	1.87594	0.13896	1.78576	0.13838			0.1689	0.1312
Denmark	2.1894	0.14217	1.17418	0.31347	1.21283	0.30944	2.67213	0.03688	4	1	0.3091	0.3032
	2.87499	0.09314	2.68579	0.07329	2.25707	0.08683	1.93595	0.11105			0.0682	0.0796
Finland	4.07291	0.04634	1.48735	0.23124	1.14451	0.33549	1.00165	0.41115	5	2	0.226	0.3295
	2.09658	0.15085	0.6206	0.53981	0.81006	0.49152	1.15743	0.33516			0.5376	0.488
France	2.28358	0.13397	2.60656	0.079	1.63325	0.18692	2.0685	0.09129	4	2	0.0738	0.1793
	43.2907	2.30E-09	3.13583	0.04795	1.45004	0.23327	1.23866	0.30007			0.0435	0.2261
Germany	6.94127	0.00979	45.1568	1.50E-14	31.7981	2.80E-14	24.5692	7.50E-14	4	2	0.000001	0.000001
	4.44415	0.03757	1.19753	0.30641	0.59975	0.61675	1.98436	0.1034			0.3019	0.6151
Greece	1.22224	0.27166	1.54823	0.218	0.9998	0.39672	0.77626	0.54356	2	2	0.2126	
	0.52933	0.46864	0.12309	0.88433	0.18541	0.90608	0.57643	0.68046			0.8842	
Italy	1.75325	0.18855	1.96744	0.14541	1.44899	0.23356	1.24151	0.29891	2	2	0.1398	
	0.12891	0.72034	3.27553	0.04206	2.05573	0.11138	1.54718	0.19516			0.0378	
Netherlands	4.01807	0.04777	3.3215	0.04029	1.66447	0.17996	1.54551	0.19563	2	1	0.0361	0.1723
	0.21568	0.64338	0.13799	0.87128	0.07472	0.97344	0.14133	0.96637			0.8711	0.9736
Norway	2.94406	0.08935	1.55199	0.21709	1.02078	0.38711	0.87248	0.48364	4	1	0.2118	0.3821
	36.1934	3.10E-08	15.5976	1.40E-06	8.44259	5.00E-05	3.06578	0.02028			0.000001	0.000001
Portugal	6.85329	0.01025	3.98062	0.02184	3.14615	0.02875	2.3337	0.06144	3	2	0.0187	0.024
	2.0752	0.1529	0.27869	0.75738	0.82203	0.48492	0.60482	0.66014			0.7568	0.4815
Spain	1.72113	0.19261	1.76734	0.1763	1.60191	0.19417	1.1981	0.31702	2	2	0.1708	
	0.00638	0.93651	5.88125	0.0039	4.28928	0.00697	3.37981	0.01257			0.0028	
Sweden	9.02708	0.00338	4.19778	0.01788	4.27712	0.00708	4.30965	0.00306	7	2	0.015	0.005
	0.33061	0.56662	6.04554	0.00337	5.15397	0.00242	2.92823	0.025			0.0024	0.0015
Switzerland	7.41171	0.00767	4.29577	0.01634	3.73522	0.01383	2.79524	0.0306	2	2	0.0136	
	0.05527	0.81462	1.46809	0.23549	1.36622	0.25792	1.58288	0.18547			0.2304	
United Kingdom	6.57699	0.01185	4.88926	0.0095	3.08599	0.03098	2.13729	0.08242	5	2	0.0075	0.0261
	1.95979	0.16469	0.34532	0.70887	0.58168	0.62848	1.60025	0.18092			0.708	0.627

Shadowed boxes indicate a 5% significance

THE AUTHOR: José Luis Cordeiro

José Luis Cordeiro is a world citizen in our small planet in a big unknown universe. He was born in Latin America, from European parents, was educated in Europe and North America, has worked extensively in Africa, Europe and the Americas, and currently lives in Asia. He has studied, visited and worked in over 130 countries in 5 continents.

Mr. Cordeiro studied at the Massachusetts Institute of Technology (MIT) in Cambridge, USA, where he received his Bachelor of Science (B.Sc.) and Master of Science (M.Sc.) degrees in Mechanical Engineering, with a minor in Economics and Languages. His thesis consisted of a dynamic modeling for NASA's "Freedom" Space Station (the "International" Space Station of today). During his studies, Mr. Cordeiro worked with the United Nations Industrial Development Organization (UNIDO) in Vienna, Austria. He later studied International Economics and Comparative Politics at Georgetown University in Washington, USA, and then obtained his Masters of Business Administration (MBA) at the Institut Européen d'Administration des Affaires (INSEAD) in Fontainebleau, France, where he majored in Finance and Globalization. He is a lifetime member of the Sigma Xi (Scientific Research) and Tau Beta Pi (Engineering) Honor Societies in North America, is also a honorary member of the Venezuelan Engineers College (CIV), and his name has been included in the *Marquis Edition of Who's Who in the World*.

Following his graduation, Mr. Cordeiro worked as an engineer in petroleum exploration for the French company Schlumberger. For over six years, he served as an advisor for many of the major oil companies in the world, including Agip, BP, ChevronTexaco, ExxonMobil, PDVSA, Pemex, Repsol, Shell and Total. Later, in Paris, he initiated his relation with the international consulting company Booz-Allen & Hamilton, where he specialized in the areas of strategy, finance and restructuring. In Latin America, he has served as an advisor for some of the most important regional corporations and has taken part in the transformation and privatization of a number of oil companies in the region. His experience and studies in monetary policy, currency boards, dollarization and monetary unions have taken him to participate in several monetary changes in Latin America and Eastern Europe.

Mr. Cordeiro is founder of the World Future Society (Venezuela Chapter), chair of the Venezuelan Node of the Millennium Project of the World Federation of United Nations Associations, director of the Single Global Currency Association (SGCA) and the Lifeboat Foundation, cofounder of the Venezuelan Transhumanist Association and of the Internet Society (ISOC, Venezuela Chapter), board advisor to the Center for Responsible Nanotechnology (CRN), member of the Academic Committee of the Center for the Dissemination of Economic Knowledge (CEDICE), the World Future Society (WFS) and the World Futures Studies Federation (WFSF), former director of the World Transhumanist Association (WTA), the Extropy Institute (ExI), the Club of Rome (Venezuela Chapter, where he has being active promoting classical liberal ideas) and of the Association of Venezuelan Exporters (AVEX), where he participated in the original negotiations of the Free Trade Area of the Americas (FTAA). He has also been advisor to the Venezuelan Business Association (AVE) and other companies and international organizations. He has lectured as an Invited Professor at several major institutions, from the Massachusetts Institute of Technology (MIT) and London Business School (LBS) to the Institute for Higher Studies in Administration (IESA) and the Central University of Venezuela (UCV), where he created the first formal courses of Futures Studies ("prospectiva") and of Austrian School of Economics in Venezuela.

Mr. Cordeiro has a fortnightly opinion column in the largest and most prestigious Venezuelan general newspaper (*El Universal*) and has also written and has been interviewed in major media (press, radio and TV) including *ABC*, *BBC*, *CNN*, *Chosun Ilbo* (Korean Daily), *El Comercio* (Ecuador), *El Comercio* (Peru), *El Tiempo* (Colombia), *El Universal* (Mexico), *El Universal* (Venezuela), *Los Andes* (Argentina), *O Estado de Sao Paulo* (Brazil), *Mainichi Shimbun* (Japanese Daily News), *La Tribune* (France), *The New York Times* and *The Washington Times.*

MAJOR WORKS: José Luis Cordeiro

Books

- *El desafío latinoamericano (second edition)*
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- *Cenários Energéticos 2020*
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