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Three essays on the development of Brazilian Amazon

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Brazilian development: dependency, endowments and the energy issue.

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Abstract

Although Brazil is the ninth world economy by 2018 – with a GDP of 2.14 trillion US dollars according to the International Monetary Fund - its growth resulted from a dependent economic development, and it is possible to distinguish three historical phases of the evolution as it occurred in Brazil: colonial phase, South-North conflict, subjection to the global market. The heterodox economic policies of the last ten years have failed to correct the path of dependence inherited from colonialism and perpetuated by major projects of national interest. So that the reduction of inequalities and the defeat of poverty remain distant objectives, despite the economic growth.

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Introduction

With a population of about 209 million inhabitants and a Gini index of 51.3[1], Brazil is emerging from its most recent economic and political crisis, following the Roussef impeachment, with a recovery in growth of +1% in the first quarter of 2017 (WB, 2018). Pension reform, privatization and taxes on imports are some of the policies proposed by the last Temer government to reduce public spending and stimulate growth, in a direction that seems to be more of dependent capitalism than of development *latu sensu* (OECD, 2018), eventually leading to the drastic political change brought about by the last elections, on 28 October 2018, of the conservative candidate Jair Bolsonaro. However, policies applied by the former petist[2] governments, rather than producing structural changes and sharpen welfare, seem to have contributed to consolidate - both internally and externally – the dependent development[3] (Traspadini, 2014). They have brought an economically backward country closer to imported consumption standards letting the economic dynamism drag levels of inequality among the greatest in the world (de Freitas Barbosa, 2012). In terms of inequality, in fact, the Federation, Federal States and Macro-regions do not present homogeneous trends. The *Amazônia Legal*[4], for example, which is rich in natural resources and that is the country's main source of hydroelectricity, has levels of inequality in the distribution of income below the national average. The state of Pará, one of the main States in the Amazon involved in mining and energy activities, has a decreasing GINI index in the last 10 years, quite high but lower than the country average (SUDAM, 2016). The Human Development Index (HDI), on the other hand, has been growing in the last 10 years (Figure 1). Not considering the issue of distribution inequality[5], it places the country in 79th place in 2017, with an index of 0.75 points, in the high human development bracket on a global scale. Unlike the Gini index, the human development performance of the North Region is almost always below the national average (UNDP, 2018). The non-uniform trend of development indices between States and between States and Federation opens the way to our research demand: to what extent

1 The latest update on the GINI index refers to the year 2015 (WB, 2018).
2 Concerning the PT (Partito dos Trabalhadores), Eng. Trans. Workers Party.
3 Reference is made e.g. to CCTs (conditional cash transfers) such as *Bolsa Família.*
4 Composed of all seven states of the Northern Region (Acre, Amapá, Amazonas, Pará, Rondônia, Roraima, Tocantins) to which are added the Maranhão (North-East Region) and the Mato Grosso (Center-East).
5 Even if not used in the present work, we point out that there is an Inequality-adjusted HDI available at http://hdr.undp.org/en/content/inequality-adjusted-human-development-index-ihdi.

economic growth at country level is able to lead the development of the so-called peripheral areas and how national development strategies are able to drive the process of regional development without exacerbating internal center-periphery dynamics? (Furtado, 2000). What we propose then is to provide tools that help to review the development agenda of the country, inducing the implementation of an integrated growth approach based on the double fight against poverty and inequality as tools for balanced development. In the specific case of the Brazilian Amazon, we claim the medium-long term objective to definitely overcome the vision of the Amazon as the "garden of Brazil" (Pinto, 2017). In fact, in order to do this, a more complex federal strategy of exploitation is needed for the sake of conservation of resources and territory, to ensure national growth and at the same time of regional integration (Magalhaes, 1987).

Figure.1 Human development in Brazil, North Region and Pará

Human Development Index (HDI)*			
	1991	2000	2010
Brazil	0,493	0,612	0,727
North Region	0,461	0,527	0,667
Pará	0,413	0,518	0,646

*The indicator used for both the North Region and the Pará is the MHDI instead of HDI

Source: Personal Elaboration from UNDP, FJP, IPEA, 2013.

In the first part of the paper, we proceed to a historical excursus of the economic phases of Brazil from the colonization up to the era of the military dictatorship. In the second paragraph, the process that leads the country first to the recovery of democracy and then to the entry into the BRICS as a leading economy in South America and among the emerging world is explained. The third chapter deals with the role that the Amazon plays in the various stages of growth and development of the Country to arrive, in paragraph four, to explore the function of hydropower as an input to both economic growth and human development. Finally, in paragraph five, we discuss data on the performance of the Amazon and in particular of the State of Pará in terms of growth and development in comparison with the results of the country.

1. A socioeconomic history of dependence

In order to understand the role of the Amazon in the Brazilian economy, it is necessary to retrace the history of the Country in the last 500 years with the aim of understand its political geography[6]. In fact since the age of colonization the economic role of Amazon has been pivotal.

1.1. Dependence on the Crown

From 1500 onwards, the Portuguese Crown, at the apogee of trade with the East, expressed its interest in the immediate occupation which was more complicated than expected: territory, climate and culture represented both a challenge and a high economic risk, so that it was not easy to encourage the sending of settlers overseas[7]. Since the first landing, in 1500, Brazil has presented itself as a territory rich in resources and completely devoid of regulation. The immensity of the territory and the low population density allowed to settle whoever wanted to do it (also seen the small number of Europeans, at least in the first phase of settlement). Thus, until 1580, year in which the Kingdom was incorporated by the Spanish Monarchy, the economic policy of the Vice-Kingdom of Portugal in Brazil was characterized by a great liberalism both internal (freedom in the use of resources for subsistence or commercial purposes, except some monopolies of the crown like the *pau brasil*[8]), both external (free access to foreigners)(Prado, 2004).

6 Political geography refers to the science that photographs a past situation by studying its historical evolution (objective), different from the geopolitics that photographs a historical evolutionary situation, present and future, trying to interpret the evolutionary phenomena (non-objective).

7 They often were adventurers and even criminals. Never exponents of the nobility nor members of big families of merchants (Prado, 2004).

8 It is a typical tree of the Brazilian coast that reaches 10-15 meters in height and has been widely commercialized and used starting from the first years of landing of the Portuguese settlers in the European dyeing shops. It gives the fabrics a red color, and is less expensive than the already used dyes derived from animal. It has been the main economic activity in the colony for the first years, before the installation of the extensive cultivation of sugar cane. However, the source of the precious red dye has already been overwhelmed by the use of wood as a construction material since the eighteenth century, with the aim of rebuilding the Portuguese merchant fleet.Brazilian timber tree. The *pau brasil* cycle occurred in 1500-1550.

After taking its control, the Spanish Monarchy extended the restrictive trade policies, yet in force in the Spanish colonies, also to Brazil, indirectly favoring the birth of smuggling. Such restrictive measures (the more restrictive the measures, the bigger the smuggling) were further maintained and strengthened even under the Crown. Starting from 1640, Portugal imposes the closure of ports to foreign ships, with some exceptions[9], and creates the Companies with their privileges with control function (i.e. limitation of smuggling) and to limit the damage caused by piracy attacks. Furthermore, the production/extraction of any potentially “inconvenient” food or goods - interfering with the commercial traffic in Portugal, with its internal production or with the interests it defended in the East[10] - was prevented. Portugal did not return to the liberalism that had preceded the Spanish domination: it was now depleted of all wealth and above all its fleet was limping, but this meant huge growth for Brazil. However, the use of its territory as a mere source of raw materials[11] has paradoxically cut off any possibility of development. This is the reason why, until independence in 1812, the country will not be able to have its own national economy. This phase is the so-called sugar cycle (1600-1800) in which Portugal defended its supremacy as the first producer and exporter of sugar from sugar cane, at least until the establishment of the Continental Block, following which the European industry started surrogating sugar can with the sugar beet (Prado, 2004).

The study of the dynamics of colonial trade, as well as of land occupation, is important to understand the characteristics of the Brazilian economic system since the colonial era. The underdeveloped domestic economy mainly operated in order to supply food to urban areas (meat and dry meat), while the rural agglomerations were generally self-sufficient. The import sector, instead, was substantially composed of other urgent goods supply[12] for both urban and rural agglomerations together with the slave trade. Maritime exportations - consisting of tropical goods[13], gold and diamonds - were sent both towards European ports and throughout

9 Entrance granted to France and the Netherlands, provided that they were integrated into any Portuguese expedition, departed from the ports of the Kingdom.

10 Portugal was not rich in its own resources, but played an important role as a commercial intermediary.For example, the exploitation of the iron mines discovered in Maranhão was prevented. In fact, although Portugal was not a producer of iron, it was through its trade that this raw material used to arrive in Brazil. However, shortly thereafter, the news of the existence of these mines was proved to be false. The production of oil and wine was instead prohibited because it interferes with the domestic production. Eventually, cinnamon and pepper were hampered because they competed with the Asian market (Prado, 2004).

11 They created a row goods supply for Portugal, by means of economic restrictions and administrative oppression (progressively all the powers and freedoms granted to the settlers returned under the direct control of the Crown, which also started appointing all delegates)(Prado, 2004).

12 European goods protected by the Crown such as salt, iron and manufacturing products (Prado, 2004).

13 Unknown itens such as bananas, pineapples, papaya etc.

the Amazon basin (the only navigable area within the country)[14]. Although the ground trade was decidedly paltry due to the "chronic war" status among the colonies of the New World, it was massively promoted at the borders by smuggling's trade of rival tropical goods[15] (Prado, 2004).

In this context, employment increased along the coast, nearby the recent installed colons' communities. Therefore, it flourished in the proximity of highly fertile lands[16], due to the presence of extensive crops (first sugar cane, then tobacco[17]) whose proceeds were exclusively allocated to the Crown trade. Starting from the coast, the process spread across the country, switching between progressive/orderly or brusque/disordered occupation. New settlements were supported by small-scale agriculture and breeding (just subsistence): rural population was usually self-sufficient, while the urban agglomerates (first small and sparse, then gradually more and more numerous and populous) had commercial contact with small indigenous communities[18]. This dichotomy of the agricultural sector is only apparently efficient. The low productivity of lands not allocated to sugar cane and tobacco have induced since the first century of occupation hunger and malnutrition (that will become chronic). In fact it required more and more space to be cultivated, and this favored the progressive exploration of the dry areas of the North East[19]. Subsequently, the attention of entrepreneurs and adventurers moved from the North (extensive plantations along the coast) to the Center-South (gold and diamonds): in a few decades, they achieved a sparse occupation of new lands and they quickly exhausted almost all the mineral potential19[20]. Thus, the occupation of the

14 The Amazon River was considered an extension of the coastline: its size (width and depth) and its navigability, in every period of the year, allowed the entrance of ships of any size.

15 Brazilian maritime exports were officially monopolized by the Portuguese, but substantially smuggled by the British (Prado, 2004).

16 Along with the diffusion of the great property and of extensive cultivation, slavery spreads across Brazil. Usually, slaves were captured in the Portuguese colonies in Africa (especially from Angola)(Prado, 2004).

17 Unlike the case of the sugar cane, the cultivation of tobacco were left to the care of women and local people and it has never risen to such importance as to represent an economic cycle in its own (Galvani, 1948).

18 They have already practiced agriculture, often nomadic, for many years, and then they found in the alimentary need of the new cities a way to access goods and standard of consumption coming from the Old Continent (Prado, 2004).

19 It should be noted that the occupation of the North East with crops and pastures had the role of supporting the occupants of the Northern coast (starting from the port of Belém). The urban conglomerates that were created around the port of Rio de Janeiro, instead, caused the expansion the south west, towards the Rio Paraíba (Prado, 2004).

20 The high costs of transportation and the absence of both adequate extraction technologies and economic foresight led to the decline of the Brazilian mining sector (e.g. the extraction areas were often isolated both from each other and from the coast; moreovere, they were not equipped with adequate communication infrastructures)(Prado, 2004).

Colony continues throughout the 1700s, marking three main directions for expansion: North (starting from Belem) for the so-called "tropical products", North East for agriculture and breeding and Central South for mines (especially Minas Gerais and Ouro Preto)(Prado, 2004).

The best lands were allocated to the most profitable crops, the worst to subsistence. This resulted in the creation of extractive poles instead of the installation of new communities, while the use of the territory has always occurred at the cost of violence and abuses, i.e. the slaughter of the Indios and the slave trade of Africans. Moreover, the exploitation of new resources was often uneconomic as well as anti-ecological since no criteria for social and environmental protection had been created until 1700, leaving room for an intensive exploitation[21] that led both to the exhaustion and then to the abandonment of the few existing gold mines, allowing Brazil to become one of the world's leading diamond exporters[22]. The age of gold and diamonds is important because it finally defines new lines of geographical expansion across the continent, but it also highlights the shortcomings of the Portuguese. Ignorance was a major obstacle to development: the low profile of settlers and the isolation of the colony did not allow, during a long time, the creation and training of neither human capital nor technical skills. Another obstacle was the absence of a systemic attitude arisen from the massive relocation of labor force from the sugar cane sector (which in the first century of occupation had even taken land from agriculture to subsistence, resulting in malnutrition and hunger) to the mining one, without any entrepreneurial strategy, but simply following a pioneering logic of the easy income (Prado, 2004).

In conclusion, the first two centuries of occupation were dedicated to a kind of primitive extraction of minerals and natural resources, in which everything had been exhausted immediately and (sometimes) inexorably (Prado, 2004).

21 Gold mines were exploited for a 50 years period of time by using firsth a large-scale and then small-scale extraction system (Prado, 2004).

22 Extraction and transport costs were very high in gold sector. However, the discovery of gold quickly led to a so-called financial orgy: the huge quantities extracted could not be controlled by the crown due to smuggling, and the settlers' inability practically prevented the start of an accumulation process, in a context in which much of the value deriving from the discoveries of gold was literally squandered in the purchase and transport of slaves from the Portuguese colonies in Africa (Prado, 2004). The short but intense golden age occurred within 1690-1770, forerunning the age of diamonds (1729-1800)(Galvani, 1948).

1.2 Dependence on the market

The liberalization of trade almost coincides with independence and took off when the king of Portugal, who moved to Brazil, abolished the Colonial Pact, establishing that all ports of the colony were open to the free market, destroying the Crown's commercial monopoly. Pushed, now, by personal interests, the King initiated a phase of stimulation of the country's economic activity, the construction of roads, the improvement of ports, the incentive to immigrants settlers, the enhancement of gold mining techniques and the abolition of the prohibition on the manufacturing sector. In this way, the industrial capital began to rise, however it was mainly invested in large-scale manufactures aiming to achieve the market, at the expense of the small local or craft producer (Prado, 2004).

As for the private sector, the development of industrial capital stimulated salaried work and helped to deconstruct an economy just based on commercial monopolies. However, Brazilian manufacturing remained weak, as it had not developed in the previous years - with the exception of the development of the textile and metallurgical sector, both distinguished by the German initiative - and it was suffering from excessive competition from the free market. The Country continued specializing itself in the production of raw materials, both the consumption and the production were stimulated, but the former reacted much faster than the latter, resulting in an imbalance of financial life. Without any other revenue beyond those deriving from export, and with the main cost represented by the purchase of slaves[23], in the new phase - characterized by the importation of higher/foreign consumption standards - the imbalance was bridged by the inflow of foreign capital which, especially in the case of loans, generated long-term interests, giving rise to the practice of “paying debt with debt”, and creating a new fragile dependence on foreign countries (Prado, 2004).

As far as the public sector is concerned, the administration of the colony was extremely inefficient, and administrative expenses were increased by the waste of the king's court, by the funds necessary for the repression of revolts, by the payment of debts to foreign countries and by a weak tax system in which the easiest and most secure source of revenue were duties on imports which, due to the most favored nation clause, was an ad valorem duty of 15% (the

23 Almost all the gold was wasted for this.

minimum value that had been granted to the British). With such an enlarged public debt[24], the main benefits from the opening of the market were the technical development, the mechanization and the improvement of navigation techniques. In addition, the abolition of slavery - that has, at least in the first period, helped to re-balance the trade balance - generated an incentive for growth and development, throughout the investment in new economic activities and the decline of monoculture specialization (Prado, 2004).

The immense wealth of the Brazilian territory, in times of great economic chaos, has managed to offer a new opportunity to the country: the cultivation of coffee, whose cycle covers the period from 1830 to 1940. The cultivation of the coffee plant, maybe imported from Africa, was introduced in Pará, Rio de Janeiro and Baía then spread out also in Center and South Regions. Thus, Brazil instantly faced the coffee market as the main producer and exporter, with absolute supremacy in Latin American. Even though coffee exports was an important asset in the country's balance sheet, incorrect policies aimed at increasing transitory profits of sales have made it lose its supremacy in the market instead of enhancing the long run competitiveness based on low price. All the three major actions that took place in 1906, in 1917 and in 1921 (further followed by the permanent defense strategy), resulted in the stocking and elimination of huge quantities of coffee, the so-called "sacrifice quotas", thrown into the sea (or even sometimes burned) with the aim of augment the return on investment thanks to the increase in the price of the reduced quantity of product placed on the market. The consequence of this strategy was a transitory price improvement that later left room to the production of coffee by other Latin Americans countries, which filled the market quotes left by the artificially reduced Brazilian export (Galvani, 1948).

Beyond the coffee, the cycle of rubber was fundamental for the development of the Amazon region, although it was very short (from 1860 to 1910) and despite repeating the parable of the golden age (i.e. blind attitude and no foresight). The main States involved in the exploitation of rubber were Pará and Mato Grosso, while Manaus and Belém were transformed from villages to flourishing capitals. However, although the rubber was present in large quantities, some problems prevented its extraction. On the one hand, the rubber extraction was extremely tiring and the synthetic rubber provided a better solution. On the other hand, the production of

24 In 1850, it amounted 40% of the total revenues (Prado, 2004)

Asian rubber generated a new strong competitive emerging market[25]. Eventually, agreements with US industries made the major contribution establishing extremely affordable prices to the US, which prevented the Amazonian production of rubber to influence the global market while getting in return jobs and infrastructures (Galvani, 1948).

The real industry, with volumetric and qualitative characteristics comparable to the European ones, have developed instead only starting from 1914, and always in conjunction with the favorable conjuncture provided by the world wars. The presence of the craft industry since colonial times has guaranteed, up to the first Republic, just the development of a rudimentary industrial sector, while during the Republic we can speak of the first real industry, in the presence of large immigration flows and the wide importing needs of the Allies, which have encouraged its growth. Between 1917 and 1940, the value of production and the number of employees went up more than four times, and also the number of industrial businesses went from 12.571 to 64.687 (Galvani, 1948). In this context the metallurgical industry (especially iron and steel), together with the electricity sector, are those which received by the state the impulse they needed, starting from the early twentieth century. Until 1920, the state offered incentives and guarantees, while between 1920 and 1930 began a policy of attracting foreign capital, which however threatened the autonomy of the country. Eventually, starting from the 1930s, Brazil started a policy of promoting the domestic industry based on the use of national manganese and coal, with plants strategically located halfway between the mines and the ports (Galvani, 1948).

Eventually, the electricity industry already showed great potential in this period. Although at the dawn of the rise of hydroelectric power, Brazil already had, as early as 1941, 907 hydroelectric plants, including the Serra de Cubatão power plant, which at the time was the seventh largest power plant in the world (Galvani, 1948).

25 Starting from the stealing of some jets of hevea brasiliensis, it was implanted in Sri Lanka, and then spreaded in Singapore.

2. An emerging economy

The years following the Second World War were characterized by the phase of industrialization by substitution of imports. Until then, the main source of revenue for the government had always been the taxation of foreign trade, but this starts to present some problems. On the one hand inflation were halving the value of duties, and on the other hand smuggling were taking away from Brazil substantial shares of the base on which the duties were applied (Galvani, 1948).

2.1. From the economic miracle to the lost decade

The first phase of the industrialization process, under the Vargas government, was characterized by large investments financed by the "tripods" of state, federal and foreign capital (restrictive monetary policy, increased fiscal pressure and attraction of foreign capital). From the second half of the fifties until the beginning of the sixties, the Kubitschek government gave priority to the strengthening of infrastructure (it was in these years that the capital Brasilia was built) with the idea that the objective of growth could be achieved by facilitating logistically the movement of people and goods. However, President Kubitschek not only increased the foreign debt but also reversed the course of monetary policies, going down in history as the president who printed money, leaving the country in the early sixties with a modern and widespread network of infrastructure but in the grip of a galloping inflation (CGEE, 2013). The government of his successor João Goulart was characterized by the progressive increase of the already galloping inflation and by an attempt of agrarian reform that made a fear for a socialist drift in line with the other governments of South America. In this context of extreme macroeconomic instability lies the military *coup d'état* that led to the dictatorship of the "Gorillas", which lasted until 1984 (Motta, 2007). The *coup d'état* was a severe blow to Brazil's democracy, but not to its growth. The first phase was characterized by a reduction in inflation and an increase in the concentration of incomes, accompanied by an increase in the tax burden, which is fundamental to guaranteeing a greater public spending. All these factors, together with the augmenting foreign debt, allowed the

Gorillas to proceed toward the implementation of major government plans, the main objective of which at this stage was the creation of large conglomerates of state-owned enterprises such as Elettrobras[26]. Precisely through the large state-owned enterprises, the regime was able to support the so-called "forced march", i.e. the process of industrialization supported by the state for the creation of fixed capital and intermediate goods (starting from the trade deficit recorded in previous years) and the severing of the economic link of dependence with foreign countries, especially at the energy level (CGEE, 2013). Brazil's great growth, financed by the high foreign debt and the enormous deficit in the trade balance, describes the Brazilian "economic miracle", which, however, came to a halt at the same time as the oil crises of 1973 and 1979, when the expansionary monetary policy, the rise in oil prices and the international liquidity crisis caused galloping inflation to rise to hyperinflationary levels. The period from 1980 to the beginning of the 1990s was defined by historians as "the lost decade". The dream of growth was abandoned and the growth rate went from a maximum of 8.9% to a minimum of 1.7% (CGEE, 2013). In 1984 the process of democratization was restarted while inflation was now considered chronic to the point of starting the debate on the effectiveness of heterodox policies, alternatives to the restrictive monetary policy which, failing to contain the increase in inflation, also marked the end of Brazil's growth project of the economic miracle. Starting from the installation of the new republic in 1985, five currency changes took place, with the objective of stabilizing the economic situation of the country, until the introduction in 1994 of the Plano Real by Fernando Henrique Cardoso (Traspadini, 2014). Cardoso's objective was to reintegrate Brazil into the international economic scenario by ensuring measures such as economic stability based on the enhancement of the national currency, political stability and the opening of new investment fronts capable of increasing the association between national private capital and international capital, all accompanied by a policy of privatization of state-owned enterprises, especially in the areas of electricity, transport and mining. Plano Real's economic policy, even though it does not bring the country back to the standards of the economic miracle, leaves it in a restored economic condition -

26 The creation of Eletrobras (Centrais Elétricas Brasileiras SA) took place officially on June 11, 1962. It is the largest company in the electric sector both in Brazil and in Latin America, whose major shareholder is the Federal Government. On June 20, 1973 occurred the creation of Eletronorte (Centrais Elétricas do Norte do Brasil S.A.), a joint-stock company of Eletrobras, whit the aim to generates and supplies electricity to the nine states of the Legal Amazon and provides energy to buyers from other regions of the country (ELETROBRAS, http://eletrobras.com/pt/Paginas/home.aspx).

compared to the lost decade - and ready to face the socioeconomic challenge of the heterodox policies of the twenty-year petist period starting from 2002 (Traspadini, 2014).

2.2. From economic recovery to the entry into the BRICS

Nowadays the Country, member of the BRICS since 2002, is proposing itself as a member of an alternative hegemonic pole on the international chessboard. While China is the leading country in the BRICS group, the trend of emerging countries in 2017 is now universally clear. Firstly, there is cooperation between emerging countries to put pressure to gain political weight in international institutions. Secondly, there are the FDIs (Foreign Direct Investments): emerging countries such as Brazil are no longer just recipients of FDIs, but they themselves generate investment in the "global South", that is the territory of the emerging countries themselves and the so-called South of the world, which includes Africa, Latin America as a whole and Southeast Asia. Finally, there is the financing activity (Garcia, 2017).

The activities of international pressure and financing are manifested above all through the creation of new financial institutions, such as the Asian Bank and the New Development Bank, which do not want to be substitutes but rather alternatives to the Bretton Woods institutions, and with an innovative *modus operandi*. Investment activity (FDIs) from emerging countries to the south-east of the world, moreover, is generating a dichotomous process that is not exactly the counter-hegemonic project expected (Hage, 2015). Investments in the "global south" are for the most part in the mining industry, almost always accompanied by investment in infrastructure, crucial for the development process and therefore extremely welcome. However, the investment activity is also of the type “within”, mainly in the hands of the extractive industry and of the agribusiness (Hage and Alexandre, 2015). The Brazilian case is emblematic of how the investments produce extraction centers (poles) whose resources are destined to the foreign market (Caravaggio and Iorio, 2016). However the displacement of resources, i.e. the imbalance of costs and benefits (i.e. the extraction costs and the benefits of using the extracted resource), is not only outward (Brazil is one of the world's leading exporters of raw materials), but it is also an internal dynamic inside the country that is particularly evident when one considers the Brazilian Amazon and the often reckless use of its water resources for the production of hydroelectric power (Caravaggio and Iorio, 2016). From here it follows to address two issues: the question of the use of resources on Brazilian territory with its North-South dynamic and the role of energy in the development process of the country.

3. Brazilian Amazon: a resource curse or renewed colonialism?

According to World Bank estimates, Brazil is a middle-income country with large resources. At a not yet advanced state of growth, these characteristics may make the Country subject to the *resource curse hypothesis*, a phenomenon that induces an economy to depend on the abundant supply of resources, favoring its specialization (in the Brazilian case, in the agricultural and mining sector destined for export) (Auty, 2001). This phenomenon prevents the diversification of the productive sectors and slows down the process of growth and development of the country, favoring the dependence on foreign markets (Auty, 2001). The path towards growth follows the most immediate and economically accessible direction: intensive exploitation of abundant and available resources (Auty, 2001). Having a large quantity of resources becomes a trap if their exploitation does not take place in an efficient and remunerative way, vice versa, at a more advanced stage of development - high-income countries - in the presence of physical capital, human capital and technology, countries manage to make efficient and remunerative the exploitation of resources whose initial endowment may be high or not (Kileber and Parente, 2015).

These dynamics of general economic development are reproduced in the most specific sector of energy. The role of the initial endowment and the level of development, in fact, influence the energy choices of a country (sources), influencing the formation of the energy matrix first, and electricity matrix then. Often the energy choices of a low/middle-income country are conditioned by the endowments, which impedes the climb along the energy ladder (Burke, 2010). The energy ladder theory envisages that a growing country is induced to progressively switch from polluting and exhaustible energy sources to clean and renewable ones, also providing for energy diversification with the aim of guaranteeing a greater energy demand together with the energy security. The incentive to climb the energy ladder inevitably depends on the type and the quantity of resources initially available to the country, so that large quantities of fossil resources or large water reserves can induce a country to remain stuck in the use of fossil fuels or in the production of hydroelectric power, leaving behind the objectives of sustainability and energy security (Kileber and Parente, 2015;Aresti and Michangeli, 2016). According to that theory, the shift toward new renewable sources has also an indirect relationship with the increase in a country's gross domestic product, since many other factors may intervene. In fact, beyond the direct role of income, which boost the country's demand for energy services, each energy source in the mix is a function of the availability of the stock of resources and of the strength/quality of the institutions (Kileber and Parente, 2015). With the help of strong institutions, which are able to generate distortions such as influencing relative prices, the increase in income can be invested in new technologies, regardless of the initial endowment, activating the income effect. This would explain why countries with high resource availability are able to get out of the endowment trap (Kileber and Parente, 2015). That is why not only the level of economic growth but also the stage of development of a country (e.g. the quality of its institutions, its degree of urbanization and the presence of infrastructures) is essential for spreading new sustainable technologies (Kileber and Parente, 2015).

Brazil, therefore, seems to have emerged from the energy trap, but the diversification process is not following the energy ladder criterion, especially as regards the electrical matrix. In fact, despite government programs such as *PROINFA*[27] are trying to deviate the independent integrated production of electricity through new technologies (such as small hydroelectric plants), the main alternative to hydropower is represented by the thermoelectric: this obviously helps to limit the energy risk, but does not follow the path, indicated by the theory of energy ladder, towards cleaner and more efficient energy sources (Burke, 2010). Moreover, large-scale hydropower itself, which contributes by 11% to the energy matrix and by 68% to the electricity one, has been strongly criticized for its environmental and other impacts (see Figure 2). Eventually, with the growth of the country, the demand for energy increased.

27 Created by Law No. 10,438 / 2002, PROINFA has the objective of increasing the participation of alternative renewable sources (small hydropower plants, wind power plants and thermoelectric plants using biomass) in the production of electric energy, favoring entrepreneurs who do not have corporate link with concessionaires. Of generation, transmission or distribution (ANEEL, available at: http://www.aneel.gov.br/proinfa)

However, while the percentage of other renewable sources increases, that of hydropower decreases, but only in relative terms. In fact, the use of fossil fuels such as wood and coal, which are at the base of the energy ladder, remains very high. Despite the great potential, the country is following a process of energy development more distorted than the expected (according with the energy ladder model), moving away from the objectives of environmental protection. Moreover, despite the constant increase in the generation capacity of the national

Figure 2. Pros and cons of Hydroelectric power plants

Field of interest	Pros	Source	Cons	Source
Environmental	Renewable source	Bagher et al. 2015	Loss of biodiversity	Bagher et al. 2015
	Leaves behind no waste	Bagher et al. 2015	Deforestation	Rocha, 2008
			Hydrogeological instability	Bagher et al. 2015
	Less GHGs emissions	Bagher et al. 2015	GHGs emissions	Fearnside, 1995
Social	Flexible and reliable (energy security)	Bagher et al. 2015	Displacement of population	Bagher et al. 2015
	Water based recreational opportunities***	Bagher et al. 2016	Mosquitos Plague	Fearnside, 1999
	Urbanization	Rocha, 2008		
Economic	Cheap production of energy	Bagher et al. 2015	Expensive construction costs	Bagher et al. 2015
	Readily available energy	Bagher et al. 2015	High poay back period	Bagher et al. 2015
	Price stability	Adrizzon et al. 2014		
	Contribute to local economies	Bagher et al. 2015	Loss in economic activities**	WCD, 2000; Bagher et al. 2015

* plants must operate for a long time to become profitable
** e.g. fishery, forestry and cattle farming
*** water sports, boating and fishing

Source: Personal Elaboration

energy park, the country has not yet managed to achieve widespread electrification, especially in rural areas (Van Els et al., 2012; Sánchez et al., 2015). This leads us to observe how the *resource curse hypothesis* is a paradigm that is re-proposing itself in the history of the Country, this time on a smaller scale. In fact, nowadays the Brazilian Amazon, although it is the main source of natural resources of the Country, is still the tail-end of the Country's development, supplying energy services and at the same times suffering lack of access (Cori and Monni, 2015).

4. Hydroelectricity for a sustainable development

Brazil, an emerging country in the midst of a political and economic crisis and in the aftermath of the Paris Agreement, is facing with two apparently irreconcilable phenomena: guaranteeing energy supply (in a context in which economic growth pushes energy demand upwards) and committing to the reduction of greenhouse gas emissions (Prado et al., 2016). The dichotomy stems from the fact that, from the point of view of the Brazilian energy supply, oil still dominates the country's mix. However, its electrical matrix is among the cleanest in the world. In fact, thanks to the great availability of water resources, since the seventies the Country started to invest heavily in the production of hydroelectric power, which has gradually grown in proportion to other sources until the twenty-first century (Do Amparo and Pinto, 1987). However, between 2006 and 2015 the domestic supply of hydropower[28] decreased in relative terms, going from 72.6% to 64% of the total supply, due to the simultaneous increase in other sources, especially the "other renewables" (EPE, 2017). In 2016, however, the domestic supply of hydroelectric power increased again, reaching 68.1% of the total supply, which in turn is 81.7% made up of renewables. The increase in the share of hydro in 2016 is due to an increase in a national installed capacity of about 9,479 MW divided as follows: 55.6% hydroelectricity, 18.1% thermal generation and 26.3% other renewable sources (EPE, 2017). In fact, if hydroelectricity corresponds to about 11.11% of domestic primary energy production, it represents 81.82% of the total renewable sources used to produce electricity. If on the one hand, it is interesting to note that the Northern Region contributes to more than 12% of the country's electricity production, on the other hand, Pará alone is responsible for half of the generation of the entire region, with 94.77% of electricity from hydroelectric sources (Figure 3).

Hydroelectric power, which had its peak of popularity in the 1970s (the period in which the largest power stations and the largest number of projects in the world were built) collapsed in popularity in the 1990s, when press and literature surveys began to highlight the shortcomings of a technology that clearly had an impact in terms of both the environment (Fearnside, 1995; Manyari and de Carvalho Jr., 2007; Barros et al., 2011) and society (Scudder, 1981; Fearnside

28 This includes public service power plants (large hydroelectric plants), self-production plants and also the share of liquid imports.

1999; Diamond and Poirier, 2010; Pinto, 2011)(Figure 2). In fact, although it was expected that hydroelectric plants would have less impact than thermoelectric ones it is not possible to deny the negative evidence that emerged ex post from the analysis of large plants in Brazil such as that of Tucuruí (Rocha, 2008; Fearnside, 1999; Pinto, 2011), Belo Monte (Fearnside, 2006; Jaichand and Sampaio, 2013; Fleury and Almeida, 2013), Samuel (Fearnside, 2005) or the Madeira Complex (Werner, 2011). According to a more modern literature, it is therefore expected that, once the elements considered to be the main cause of impact (i.e. the dam and the reservoir) have been eliminated or simply reduced in size (scale reduction), a positive evaluation of the small hydroelectric plants can be reached (Bagher et al., 2015). In this case, the proliferation of small hydropower plants, beyond being compatible with the objectives of energy security (diversification) and sustainability (no environmental/social impact), would also make it possible to achieve a third development objective, namely rural electrification (energy access)(Van Els et al., 2012; Sánchez et al., 2015). In terms of hydroelectricity production and taking into account the need for improve the rural electrification, the Brazilian Amazon is a crucial area. In fact, although the Brazilian Amazon hosts one of the largest water reserves in the world, guaranteeing an enormous hydroelectric potential to its Country (Figure 4), the lack of rural electrification continues to represent a serious problem even after the installation of large hydroelectric projects such as Tucuruí or Belo Monte (Tundisi at al., 2014). Usually the environmental and social costs, if demonstrated and evaluated, mainly affect the population living in the surrounded area, while the energy produced is fed into the SIN (Sistema Interligado Nacional)[29], whose main users are the large urban centers (especially in the extreme south of the country) and the industrial poles (Fearnside, 2016). The distribution of costs and benefits related to energy production is decidedly unequal and it is also accentuated by the high costs for the extension of the transmission grid to isolated small and medium-sized communities which therefore remain isolated (Van Els et al., 2012). Off-grid solutions, although more expensive and less efficient than a normal connection to the SIN, can even become economically competitive when the connection to the national grid of particularly remote areas is complicated by the absence of infrastructure (Aresti and Michangeli, 2016). In this perspective, federal programs such as PROINFA[30] and *Luz para*

29 The SIN is the Brazilian electricity generation and transmission system. It consists of a set of facilities and equipment that enable the supply of electricity in the regions of the country that are electrically interconnected, according to applicable regulations. It has four subsystems: South, Southeast / Center-West, Northeast and most of the North (ONS, available at: http://ons.org.br/paginas/sobre-o-sin/o-que-e-o-sin).

30 See note 27.

Figure 3. Hydroelectric contribution to Federal, Regional and State generation

Electricity production (Mw)*					
	2014	2015	2016	Hydro in 2016	Hydro on total energy production (%) in 2016
Brazil	590.479	581.486	578.899	380.911	65,80%
North Region	80.700	87.111	72.206	63.097	87,38%
Pará	41.951	30.304	31.774	30.111	94,77%
North contribution to national production (%)	13,67%	14,98%	12,47%	16,56%	
Pará contribution to national producion (%)	7,10%	5,21%	5,49%	7,90%	

Source: Personal elaboration from EPE, 2017.

Figure 4. National hydroelectric potential per region

Hydroelectric Potential in 2015*					
	Tot. (Gw)	Operating (%)	In construction (%)	Studied (%)	Estimated (%)
North	11,4	0,2	0,118	0,391	0,291
North East	22,1	0,221	0,0003	0,447	0,029
Centre West	39,5	0,395	0,034	0,441	0,216
South East	43,9	0,439	0,004	0,318	0,092
South	41,7	0,417	0,015	0,307	0,088

*power plants >50MW

Source: Personal elaboration from SIPOT, 2016.

Todos[31] play the role respectively to encourage the installation of small power plants for the remote production of electricity from renewable energy in isolated areas (in the Amazon, especially mini-hydroelectric power plants) and to promote the access to capillary energy of the population (Sánchez and Torres, 2015). In this apparently positive context, the main criticism of the Federal intervention is the welfarist approach, which totally lacks a precise commitment to the creation of empowerment in the energy sector of rural realities (Gouvea, 2016). Cultivating human capital also within rural areas through basic education and specific technical training would start a virtuous circle: entrepreneurial ability and cooperative management could be both cause and consequence of electrification, allowing the areas concerned to emancipate themselves from the rest of the country and from abroad thanks to the energetic, economic and finally also cultural independence (Sanchez, 2015).

5. The numbers of development

A crucial topic relating to the exploitation of natural resources is the exploitation of water resources in the Amazon region. Though intended for noble purposes, such as energy production to allow Brazil to gain energy independence from the rest of the world, this use of water generates notable impacts affecting both environment and social life (Caravaggio and Iorio, 2016). Moreover, private investors and also public companies, which are the main actors, are usually more interested in focusing on the expected revenues from the energy sector than providing basic welfare services for locals, thus undermining the process of universalize both access to water and access to energy (drivers of development). In fact, national energy strategy often benefits external actors by means of profit leakage or tax relief, while generating a negative impact on the local population. In fact, although national investments in energy production are conceived as inclusive, they tend to imply a small number of local concerns (Buarque, 1987). Brazilian energy strategy, endangering

31 Is a programme that has been launched in 2003 by the Lula government with the aim to eliminating the electric exclusion of families living in rural areas. The Program prioritizes the beneficiaries of the programme *Brasil sem miséria*, rural schools, quilombolas, indigenous people, settlements, riverine communities, small farmers, families in extractive reserves or affected by electricity projects/community water wells (MPDG, available at: http://www.pac.gov.br/agua-e-luz-para-todos/luz-para-todos/go).

environmental conservation and threatening local culture and economic activities, transformed the issue of the resource exploitation of the Amazon Region for energy purpose from a technical scientific issue into a social-political matter (Prado et al., 2016).

The Brazilian Amazon is a region that corresponds to 64% of the Brazilian territory. It involves nine states, that is, Acre, Amapá, Amazonas, Pará, Mato Grosso, Rondônia, Roraima, Tocantins and part of the state of Maranhão. Among them, the state of Pará is one of the largest states, located between two river basins, the Amazonas and the Tapajos[32]. Due to its abundance of resources, it has been affected by one of the biggest projects of national interest that Brazil has ever had: the *Grande Carajàs Program*[33]. This program has included a number of projects, among which the hydroelectric power station of Tucuruí (in the Pará state) which is currently Brazil's largest power station. Since Pará, in addition to being the largest state in the Brazilian Amazon, has seen its territory as the main object of the intervention of the Program, is noteworthy at this point to focus on the performance of its 143 municipalities which have been directly or indirectly affected projects of national (or sectoral) interest (Iorio et al., 2018). With reference to the *Grande Carajàs Program*, Figure 5 highlight a target group of municipalities directly affected by some major investments[34]. The M1 group includes the area upstream of the Tucuruí hydroelectric plant, while the M2 group includes the downstream ones. M2* refers to the municipality of Barcarena, which hosts two large aluminum and iron production plants respectively, beyond the harbor of Vila do Conde. Finally the M3 refers to the municipalities affected by the Belo Monte hydroelectric power station[35], while the group M4 refers only to the municipality of Santarém, highlighted as the

32 The state of Pará is located in the North Region of Brazil, with a territorial extension of 1,247,954,320 km², it has an estimated population of 8,175,113 million inhabitants in 2015 and a density of 6.07 hab./km² (FAPESPA, 2016).

33 The programme was officially established by Decree-Law No. 1831 of 21 October 1980, which established a special scheme for granting tax and financial incentives for investments located in an area of 90 million hectares, divided as follows: 53 million hectares belonging to the state of Pará, 31 million hectares in the state of Maranhão and 9 million hectares in the state of Goiás. The programme included specific projects: the Carajás iron mine, the Albrás-Alunorte refinery, the Tucuruí hydroelectric plant, the Carajás-São Luiz motorway and the Porto de Vila do Conde (in Barcarena).

34 In this case, we refer to the municipalities affected by the Tucuruí hydroelectric power station, the Alubrás-Alunorte plant and the harbour of Vila do Conde. The municipality of Santarèm, which hosts the Silvio Braga hydroelectric power station, is also considered on the map: this last power station was installed before the *Grande Carajás Programme*, but it is considered as impacting as a large hydroelectric power station (>30Mw. ANEEL, available at http://www.aneel.gov.br/).

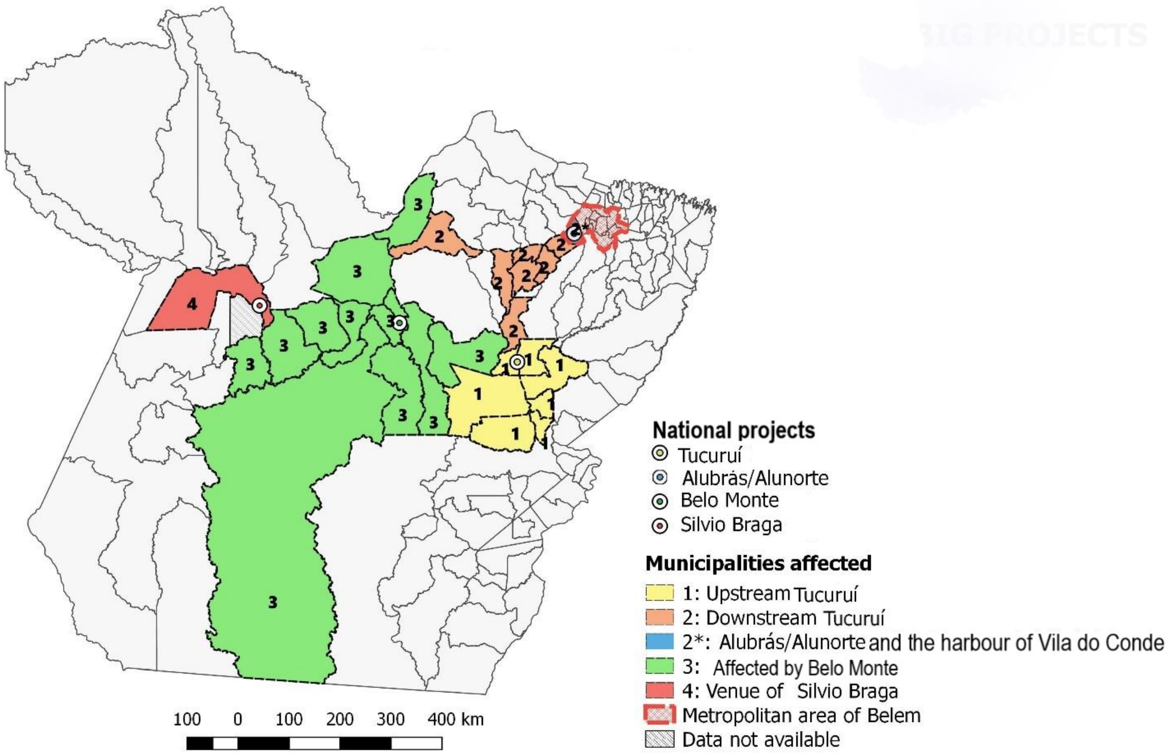
35 The Belo monte power plant started working in 2016, after about 10 years of gruelling battles by the local population against the Brazilian government and the Norte Energia, the company responsible for the investment. At the time of the research, therefore, the plant was not yet in operation, but the construction site was already active.

area hosting the hydroelectric plant of Silvio Braga (Iorio et al., 2018). By building our analysis on the georeferencing of census data provided by the IBGE (1991, 2000 and 2010), it is possible to map Pará's performance over the 20 years considered in terms of average income, in terms of the percentage of people vulnerable to poverty and in terms of inequality. As the years go by, per capita income increases on average at both federal and state level, and performance also improves within the target group, indicating an undeniable improvement in economic wealth (Figure 6). However, in each year the substantial increase in average income occurs along with more or less stable levels of inequality (Figure 7). In fact, in 2010 Brazil had higher levels of inequality than in 2000, which in turn recorded an increase compared to 1991. Pará instead returns in 2010 to levels of inequality equal to those of 1991, after an increase of 0.02 points in 2000, while the target group in 2010 returns to the levels of inequality of 1991 after a slight increase in 2000. The Gini index is the only indicator in which target groups register worse results than both the country and the state. (Figure 7).

As far as vulnerability to poverty is concerned, in 1991 there was a high percentage of the vulnerable population at all levels of dis-aggregation, but a considerable reduction was recorded in 2000, with a further improvement in 2010. The best result is that of Brazil, followed by Pará and the target group (Figure 8). In the case of Tucuruí (M1, M2), Altamira (M3) and Santarém (M4), for example, in both decades the reduction in the percentage of the population vulnerable to poverty is less than proportional to the increase in per capita income. The opposite trend is manifested only in the case of Barcarena (M2*). Therefore, at all levels of dis-aggregation, the substantial increase in per capita income occurs with the constant presence of inequality, suggesting a plausible justification for the unsatisfactory reduction of those vulnerable to poverty (even if there is an increase in incomes). However, it must be concluded that it is not possible to describe an average trend for the twenty years taken into consideration for two reasons: on the one hand, there is the lack of intermediate data (between one census and another); on the other hand there is the heterogeneity of the behavior of municipalities (as can be seen from Figures 6,7 and 8).

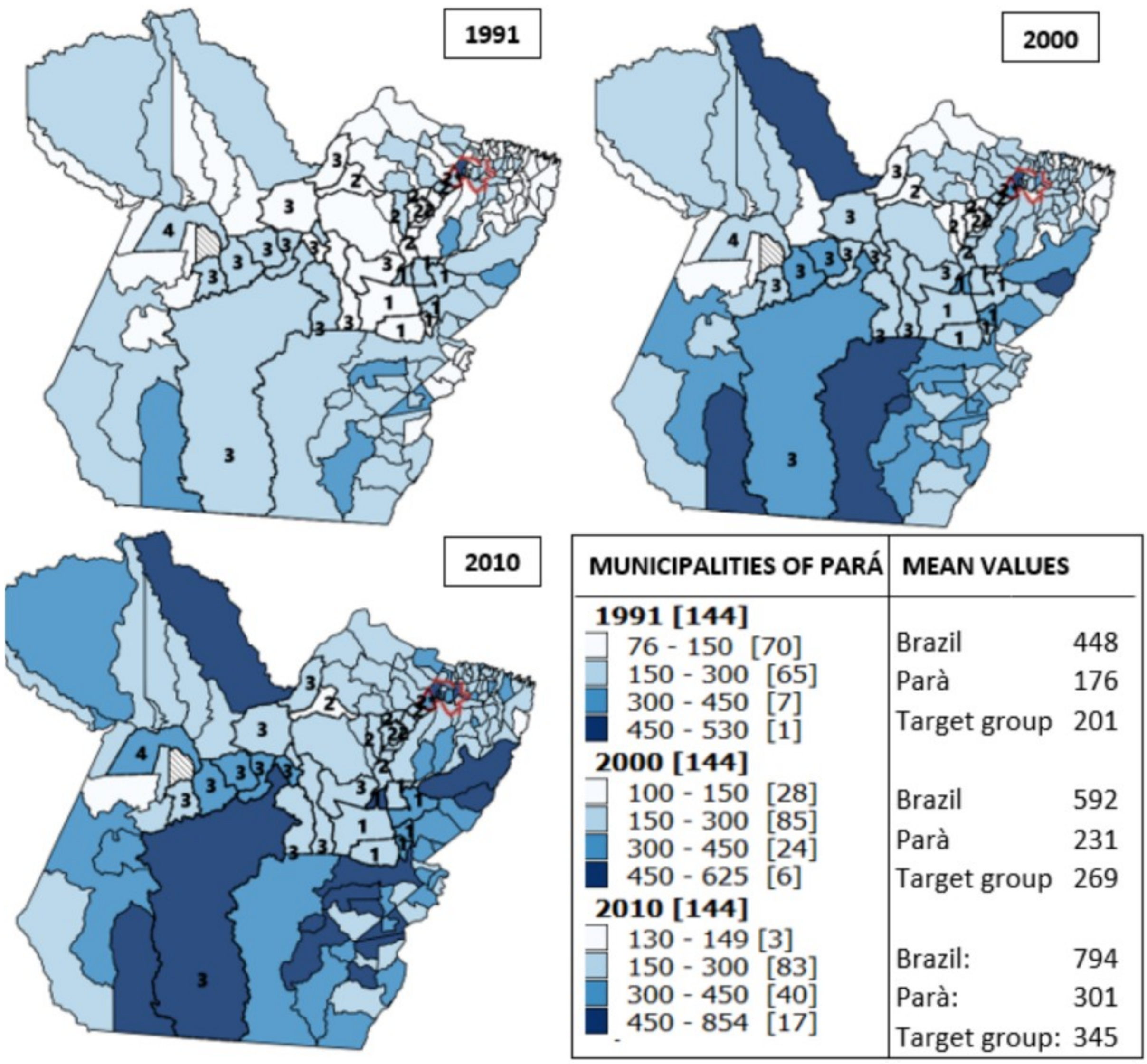
Assuming that there is a logical dependence between per capita income and human development (due to the calculation of the HDI and the MHDI) the data showed in the maps suggest the existence of a trade-off between national and local growth/development. This should be indicative of the results induced by a sector-based development approach: though it assures a great influx of capitals if in the absence of adequate structural policies means it risks to merely contribute to national economic growth whilst overlooking both the growth and the human development in affected areas (Caravaggio and Iorio, 2015).

Figure 5. Municipalities affected by sectoral projects in Pará



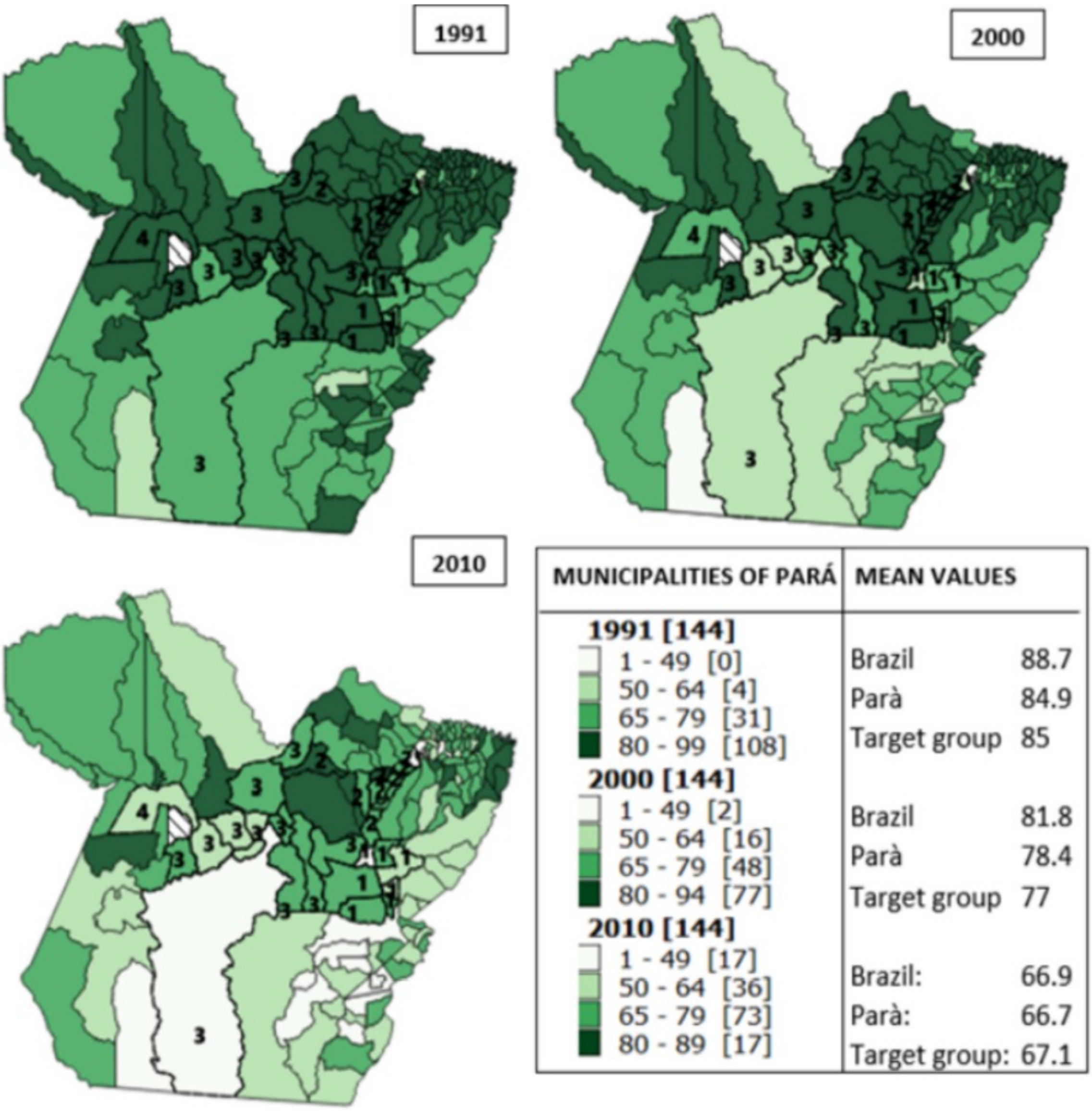
Source: Personal elaboration from IBGE

Figure 6. Income per capita in Pará



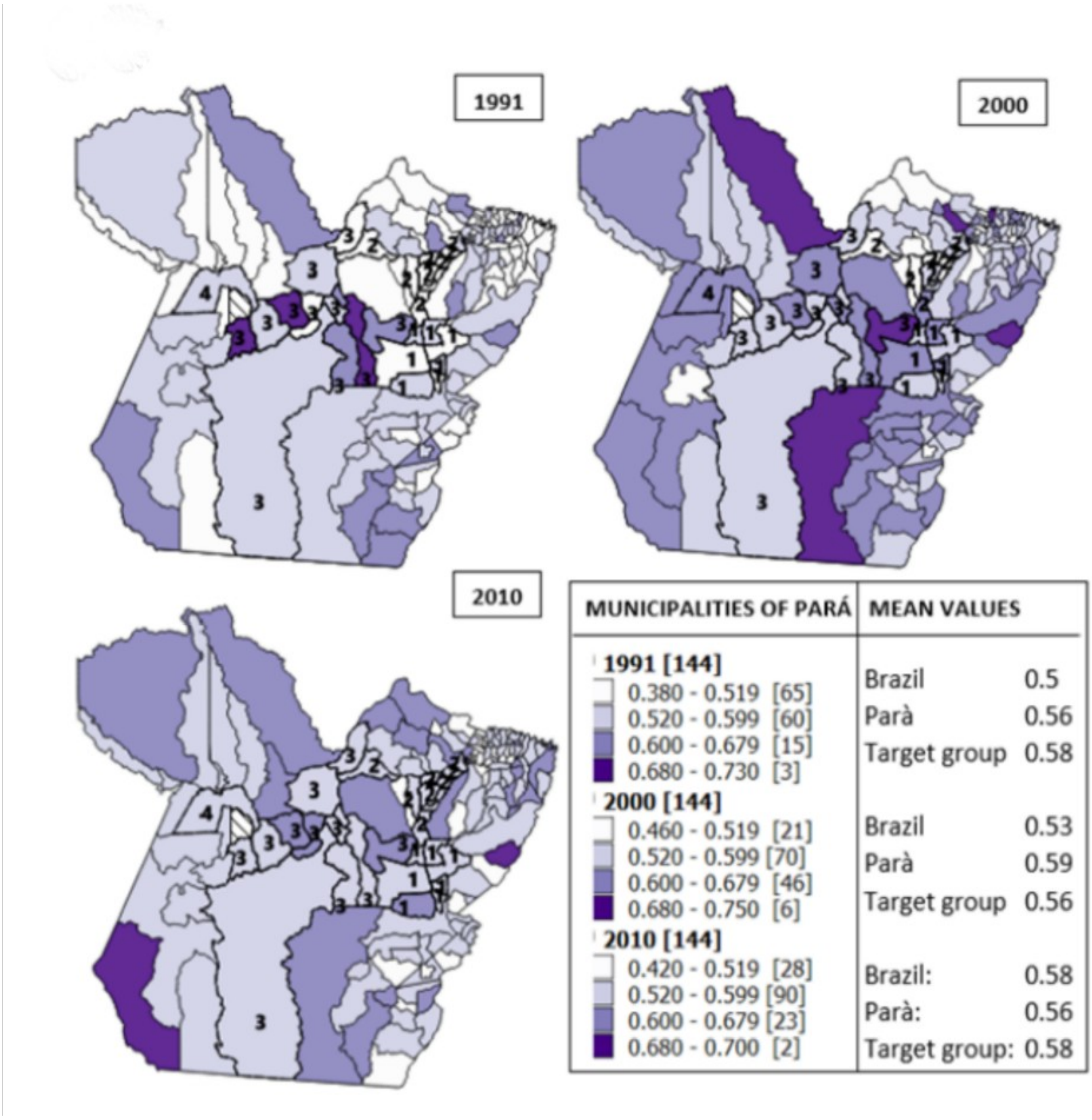
Source: *Personal elaboration from UNDP, FJP, IPEA, 2013*

Figure 7. % of population vulnerable to poverty in Pará



Source: Personal elaboration from UNDP, FJP, IPEA, 2013

Figure 8. Gini Index in Pará



Source: Personal elaboration from UNDP, FJP, IPEA, 2013

Conclusions

The lack of strong institutions, in the dynamics of energy, emphasize the problem of the north-south relationship within the country. The construction of extraction poles and infrastructures for energy purposes has been a form of occupation of the Amazon for decades. The Amazon, seen as something exotic by the colonists who for centuries exploited it for the production of goods for trade, continues to be considered as something exotic by Brazil itself. Many authors denounce the use of the Amazon as a "garden of Brazil", due to its role in the national development strategy (Pinto, 2017). The Amazon, an area rich of mineral resources as well as of water resources of national and world interest is constantly undergone accelerated occupation through the installation of energy projects (such as hydroelectric plants) or mining industries, the construction of infrastructure (e.g. motorways), the occupation of land for cultivation, all these following the leitmotif of deforestation (Becker, 2005). In the same way, both temporary (labor force) and permanent (qualified personnel) immigration are linked to large projects and represent a demographic change, and therefore an economic and social one, which is necessarily irreversible (Magalhães, 1987). Amazonian development is therefore driven by a "conservative modernization", in which the national project is the victim of external pressures (big foreign capital[36]), thus creating a framework in which the social and political exclusion of the population is perpetuated - exclusion that makes difficult even just to imagine a national development project! (Domingues, 2002).

The national economic and energy strategy is not inclusive by nature: it justifies the exploitation of resources anywhere in the name of the national interest. However, the top-down nature of the intervention, with no bottom-up approach or just fictitious participation procedures, makes the development process extremely unbalanced within the country system. By definition, the development in its broadest sense that transcends the mere economic vision must be sustainable, that is, it must respond to distributive aspects with the passage of time (Thomas et al., 2002). It is, therefore, necessary to find a balance between exploitation and conservation, both in FDIs (not to repeat the north-south dynamics in a south-south perspective) and in national energy strategy, in order to avoid getting stuck into an unbalanced development. In fact, in a territory like the Amazon, where the use of natural resources

36 The Major National Development Programs are mostly dependent on foreign capital (Torrente, 2012).

inevitably leads to a debate on the question of territorial occupation and competitive use, it is necessary to make theoretical observations that have a lot to do with practice in terms of displacement of benefits and preservation of cultural identities (Magalhães, 1987). The capitalist dynamic, not necessarily monopolist, tends to dis-aggregate the preexisting structure, both in the case of territory and in the case of productive systems. It usually brings benefits of an investment to subjects who do not belong to the local contest, while social and environmental costs of an investment usually impacts on local population (Magalhães, 1987). In this case, the share of absorption of the population at the employment level may give us a suggestion of the benefit that an investment is bringing locally, e.g. whether, when and how the majority of the population has been reabsorbed in the production process or whether or not the process of marginalization has occurred. However, the use of completely innovative technologies, the massive influx of immigrants (labor force) and the absence of a well-established popular initiative, has made reabsorption very difficult in the case of the occupation of the Amazon (Magalhães, 1987). According to Magalhães (1987), large migrations threaten the economic base, while infrastructures threaten the natural environment (both important parts of a people's culture). This lead to the loss of cultural identity, another great cost for the territory and the local population.

Major energy projects then become only a means for the occupation of a territory that is considered by the country *other than itself*[37]. The exploitation of resources and the territorial occupation, in the absence of a regulatory and controlling role of the State, risk prevailing over the conservation and protection of territory, people and culture, making the problem of the future Amazon a problem that is not scientific nor technical, but rather social and political.

In view of the above, it is important to note that, since the time of Great Brazil[38], the Amazon has been the subject of national (or so-called sectoral) development projects which have not always produced the expected development results at regional level. In particular, projects of regional interest receive a limited allocation of resources compared to national projects, which are often financed by large foreign capitals, and are often not accompanied by regional development strategies such as the development of the capacity to self-regenerate the process or the ability to retain the income generated. Conversely, sectoral projects of national interest

37 Plato, Il Sofista.

38 The era of Great Brazil (or of the Economic Miracle) coincides with the Fifth Republic, that is, with the so-called period of the Dictatorship of the Gorillas (1964-1985)(Motta, 2009).

have wider impact since including local development objectives as part of the whole. However, despite having a greater impact because of the large funding, it is not concentrated on the territory, showing a flight of benefits out of the local context after the resources exploitation through national incentives (Magalhães, 1987). For example, the *Grande Carajàs program* had some main national objectives: the increase the exportations of raw materials, the replacement of the imports and the absorption of foreign savings. An important role has been played by the iron/aluminum mining and refining industry of Barcarena, active since 1985, together with Tucuruí hydroelectric power plant, which were built in 1984 with the precise objective of supplying energy to the foundry. Both located in the state of Pará, played a massive role in the national production of refined aluminum and hydroelectric power respectively. However, the results in terms of the development of the state of Pará, although in line with the country's performance, do not exactly meet expectations[39].Actually, the objective of increasing foreign payment capacity by increasing exports was the main one among the major objectives, despite being the one that least benefited the region (Do Amparo and Pinto, 1987).

39 These projects seem to have remained regional enclaves.

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Ph.D. in Economics

CYCLE XXXI

Second Paper

Lack of energy and water access from a human development perspective.
The case of municipalities of the State of Pará, in Brazilian Amazon.

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Abstract

The aim of the paper is to measure the results achieved by the municipalities of the State of Pará between in 1991, 2000 and 2010 from a human development perspective. Having verified the role of access to water and access to energy in the development process, the objective is to identify a more exhaustive method for measuring it. The Principal Components Analysis of (PCA) allows us to reduce the number of variables and to create a new indicator of human development, alternative to the Municipal Human Development Index - MHDI, by taking into account also the accesses. The new indicator is used to rank the municipalities which have been previously ordered also on the basis of the MHDI. The comparison of the rankings shows which are the municipalities whose achievements worsen if we take into account the accesses. The outstanding results, making particular attention to the microregion of Tucuruí, suggest that considering the quality of supplied clean water and energy may affect to any extent the measurement of human development at the municipal level. Therefore, in the light of the results, the belief that hydroelectric power plants, as is Tucuruí, are able to boost the development in the state of Pará may be questioned, while more effective selection in beneficiaries are recommended when development policies are implemented at the local level by the Federation.

JEL Codes: O15, O44, O54

Keywords: Micro region of Tucuruí, Human development, Principal Component Analysis, energy access, water issue.

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Introduction

According to the capabilities approach, human development can't be properly guaranteed, neither achieved nor assessed just taking into account GDP or income per capita (Sen, 2000). In fact, satisfying the needs and achieving the goals of every human being is not only a material issue: just think about the value of a good education or the importance of an early diagnosis. The material means, therefore, retains its importance while becoming functional to the one's personal purpose which is the personal achievements (Sen, 2000). For the sake of the fulfillment of simple survival needs or at least the achievement of a basic quality of life, the development path of a country should be primarily based on a regular access to a wide range of resources. At more advanced stages of development, this issue especially refers to energy sources which are pivotal in order to ensure the fulfillment of not only social but also environmental needs. In fact, reliable access to energy in general and a fair access to electricity, in particular, is the mean through a Country can enhance, among other things, education and health performances (Brand-Correa and Steinberger, 2017).

In Brazil the matter of energy is closely linked to water since more than 60% of the Brazilian electricity matrix is supplied by hydroelectric power mostly produced in the Amazônia Legal (ANEEL, 2018)(Figure 1). The *Amazônia Legal*[40] accounts for the 64% of the Brazilian territory and is rich in natural resources the exploitation of which has given a strong impulse to the economic growth of the area and the country for decades[41] (Fapespa, 2016). However, although the area distinguishes itself in the economic sphere due to its consistent energy production, it has high-income inequalities that have remained stable over the last thirty years, albeit below the national average (SUDAM, 2016). Moreover, the data confirm that both access to water and access to energy are not universally guaranteed and it seems to be the alarm bell of the uneven trend between growth and development, both at the federal level and at the regional one (UNDP, FJP, IPEA, 2013).

In fact, historically, the *Amazônia Legal* has been the subject of national development projects since the seventies, thanks to its enormous availability of resources (Beker, 2005). The

40 Composed of all seven states of the Northern Region (Acre, Amapá, Amazonas, Pará, Rondônia, Roraima, Tocantins) to which are added the Maranhão (North-East Region) and the Mato Grosso (Center-East).

41 e.g. think of the rubber boom or the aluminium pole.

Grande Carajàs Program[42], launched in the early eighties in the state of Pará, is a classic example of a program defined as "national" or "sectoral", which included the implementation of a series of related investments within the region. Two of the main investments are the iron and aluminum extraction and refining industry in Barcarena, active since 1985 and the Tucuruí hydroelectric power plant, active since 1984 and built with the aim of supplying energy to the foundry (Magalhães, 1987). Today both have a massive role in the national production of refined aluminum and hydroelectric power respectively, while the state of Pará has shown a growing participation in the national GDP. In fact, in 2014 it provided 40.44% of the GDP of the North Region, covering 2.16% of the national GDP[43].(Fapespa, 2016).

Figure 1. Electricity production per States in the Amazônia Legal

States (Federation Units)	**Electricity Production Gwh***		
	2011	**2012**	**2013**
Acre	203	377	234
Amapá	1.566	1.704	1.816
Amazonas	9.036	9.561	9.970
Maranhão	1.943	3.621	11.181
Mato Grosso	7.200	10.802	12.361
Pará	43.092	41.217	41.191
Rondônia	3.214	4.173	6.407
Roraima	133	128	169
Tocantis	10.650	12.747	11.881
Amazônia Legal	77.037	84.330	95.210
Brazil	531.758	552.498	570.025
**including self-production*			

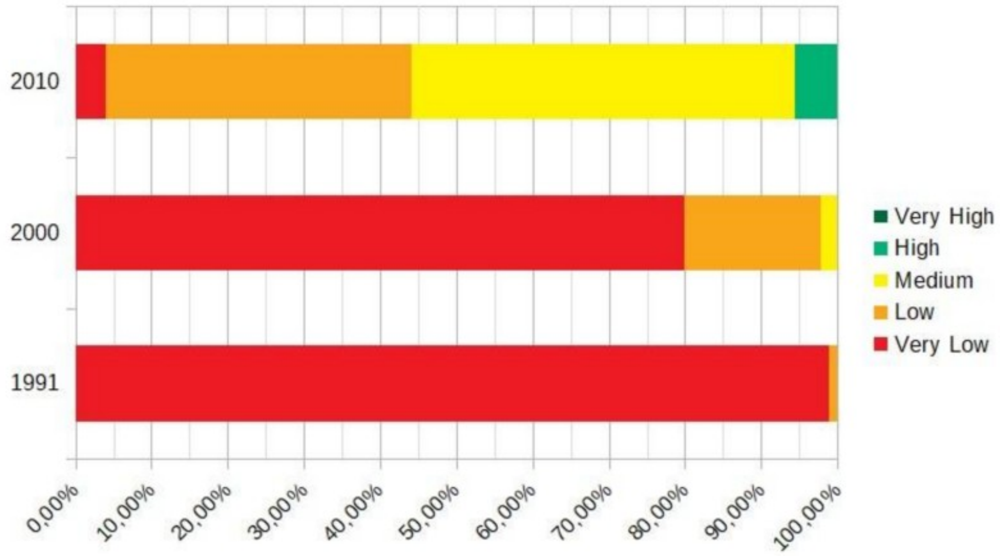
Source: Personal Elaboration from MME and ANEEL, 2017

42 The programme was officially established by Decree-Law No. 1831 of 21 October 1980, which established a special scheme for granting tax and financial incentives for investments located in an area of 90 million hectares, divided as follows: 53 million hectares belonging to the state of Pará, 31 million hectares in the state of Maranhão and 9 million hectares in the state of Goiás. The programme included specific projects: the Carajás iron mine, the Albrás-Alunorte refinery, the Tucuruí hydroelectric plant, the Carajás-São Luiz motorway and the Porto de Vila do Conde (in Barcarena).

43 The second state of the North Region in terms of GDP is Amazonas. After decades of exploitation of rubber and other natural resources, since the last seventies the federal government boosted the growth of the Industrial Pole of Manaus. The main objective was to accelerate the industrial revolution in the region and today the industrial park has a diversified production, with particular attention to electrical materials (although in both Amazonas and Pará the mining activity still represents a strong part of the local economy, while agricultural production is focused mainly on traditional but strategic crops such as rice, cassava and tropical fruits (Fapespa, 2016).

Source: Personal Elaboration from MME and ANEEL, 2017.However, despite the economic activities related to the exploitation of abundant resources, the average score of Municipal Human Development Index (MHDI) in the North Region is only 0.667, one of the lowest in the country. Only five of the seven northern states have reached the average human development level. Out of these, the State of Pará hosts the worst municipality in the Country, Melgaço, that have an MHDI of 0.418 (Figure 2).

Figure 2. Distribution of Municipalities by the level of human development (North Region)



Source: Personal Elaboration from UNDP, FJP, IPEA, 2013

Therefore, although sectoral projects of national interest are generally presented by policymakers as capable of stimulating both national growth and local development, the results in terms of development do not exactly meet expectations. The asynchronous development trend of the North Region compared to the Country should be seen as a cause for reflection. Although sectoral programs usually absorb more funding than regional ones[44], satisfactory results for the national economy keep pace with the flight of benefits from the local context. The flow has a double direction: from local to national and from local to foreign, preventing the economic growth to drive local development. Eventually, what is

44 Foreign investments that support large projects are attracted by the strong demand that in the case of regional or local development projects is not sufficiently attractive.

going on in Brazil is that national development strategies do not always seem to be able to drive the regional development process without increasing the internal core-peripheral dynamics (Furtado, 2000).

In this article, we attempt to address two objectives. In the first section, by reviewing methods and approaches, we question whether it makes sense to try to measure the impact of electricity consumption on human development rather than on economic growth, which is more widespread in the literature. In this regard, an exploratory analysis of the data is presented to support the idea that it is necessary to study the impact of access and not so much that of consumption. At this point, in order to prepare the field for the estimation of the impact of access on human development (which will be developed in the third article) in the second section we investigate which is the best way to measure human development, and especially if the widespread use of the human development index by the United Nations is satisfactory from the information as well as methodological point of view. Particular attention will be paid to the issue of access to electricity and, secondly, also to access to water since it is the main hydroelectric source, especially in emerging countries such as China, Brazil and India (Kileber and Parente, 2015).

1. The impact of energy access on development

1.1. The matter of water as an energy source

Although the recently Sustainable Development Goals seems to even resemble a mere technocratic exercise, the focus on sustainable development in developing economies should become more and more pivotal in the next years (Monni and Pallottino, 2015). For the Agenda 2030, the first objective of a sustainable economy is the fight against poverty, which cannot be assessed taking into account only income (Alkire, 2007). According to the United Nations, basic services[45], as well as income, are *means to the end* of reducing poverty, whatever its dimension, that is, to the achievement of at least nine out of the seventeen Sustainable Development Goals (UN, 2017). In fact, since per capita income and GDP measure economic prosperity, their scarcity may lead to any kind of deprivation, that is poverty, such as malnutrition, hunger, limited access to education and basic services, lack of decent work, social and gender discrimination and so on. Therefore, measuring poverty means to measure deprivation at various levels (FAO, 2017)[46].

In its discourse on the determinants of development, the UN describes water as a primary commodity necessary for survival and functional to the achievement of the objective two - reducing hunger in the world. However, the availability of water resources or the feasibility of their access is not sufficient as indicated in objective six – clean water and sanitation, since the water that one access must be compatible with the his basic needs of use. Water is a vehicle for disease, especially where the development process is in its initial phase or its level is chronically low albeit ascending, then its proper treatment is a guarantee of good health and well being, as requested by objective three – good health and well being (UN, 2017). Eventually, an equitable distribution of water in terms of both treatment and access is a tool for reducing inequalities, protecting the marina and terrestrial environment and also achieving sociopolitical balances that allow the strengthening of international partnerships for the sake of sustainable human development (UN, 2017).

45 Access to water and sanitation and access to electricity.

46 FAO is the UN agency responsible for 21 SDG indicators (related to objectives 2,5,6,12,14,15) and is a contributing agency for a further 4 (related to objectives 1, 14, 15). Because of its custodianship, FAO is supporting countries' efforts in monitoring the 2030 Agenda (available at http://www.fao.org/sustainable-development-goals/indicators/en/).

However, Monni et al. (2018) and Caravaggio and Iorio (2016) indicate the conflict of use as one of the main issues related to water. In fact, historically, the basic use of water may conflict with its agricultural and livestock purpose (Lathuillièree et al., 2016). However, more recently the problem of conflict of use has expanded to the intended use for hydroelectricity production (Fernandez, 2017). In these cases, obviously, the question of water is not expressed in a problem of scarcity, but rather of access (Victor et al., 2014). In this sense, with regard to the role of energy access, highlighting the correlation between economic prosperity and energy consumption, Galvin and Yaeger (2009) argue that lack of access to energy comes together with the scarcity of incomes, the main cause of the poverty gap in the world. It is possible to distinguish different social conditions which are co-determined by the simultaneous increase in per capita energy consumption (kWh/capita) and in per capita GNP (Galvin and Yaeger, 2009). Far below the threshold of 1000 kWh/year, there is just survival guaranteed by access to water and sanitation - as well as food. Simple access to energy in conditions of very low income would be instrumental only to the achievement of UN's objectives two - zero hunger and six - clear water and sanitation. Just above the survival threshold, energy access also favors education in terms of at least literacy, compatible with objective four – quality education, and improving the quality of life through the achievement of objectives three - good health and well being and sixteen – peace, justice and strong institutions (UN, 2017). Far above 1000 kWh/year per capita, the use of better quality education (objective four) together with an increase in well-being dictated by the increase in gross national product lead to greater environmental awareness, thus being able to promote not only the achievement of objectives thirteen (climate action) and fourteen (life below water) but also objective seven related to affordable and clean energy. Eventually, when the increase in energy consumption, is socially and environmentally sustainable, and when it is accompanied by substantial economic growth, then we can talk about technologies and innovations and peace at global level, and this allows us a final association with objective seventeen concerning the partnership collaboration for the goals (UN, 2017).

In the light of the above, considering access to water as a need for survival, energy consumption can be considered as a proxy for well-being as well as GDP or per capita income. According to Van Els et al. (2012), providing widespread access to energy in emerging countries becomes central to human development. Reducing inequalities is therefore also a cross-objective if we note that, while the lack of access to energy tends to increase social asymmetries between urban and rural context and also within the same urban context, *vice versa* the scheme proposed by Galvin and Yager (2009) would better work in the absence of extreme concentration of income (Pereira et. al, 2010). It is pointed out that if energy consumption is not oriented towards diversification and access to new clean and renewable energy sources (as suggested by objective seven - affordable and clean energy) it may not generate an improvement in well-being. There may even be a deterioration in living conditions due to the unsustainable, massive and inefficient use of abundant sources (e.g. hydroelectricity in Brazil) due to the high cost and low quality of self-production from renewable sources (e.g. small hydroelectric power plants and self-production hydroelectric plants in the Brazilian Amazon) (Pereira et. al, 2010). It is interesting that Burke (2010) notes that high levels of economic growth and development do not necessarily imply the renewal of the energy matrix, especially when there are abundant resources.

Within the framework of access, the development process of Brazil is interesting. In fact, as Pereira et al. (2010) point out, Brazil, the emerging country and leading economy of South America, is not a poor country, but a country rich in capital and resources (especially energy) poorly distributed. The country does not experience a real scarcity of resources but suffers the continuous misallocation of resources - first and foremost water - because of poverty, inequalities and mismanagement (de Souza et al., 2016). The Amazon, therefore, plays a very important role in the Brazilian economy because of the enormous quantity of water it owns, but it also became the bone of contention between national economic interest and local development strategies. Brazil is divided into 12 hydrographic regions, and the Amazon hydrographic region represents alone 40% of the Brazilian territory (CNRH, 2003). The Amazonas basin retains 60% of the country's water resources, most of which are still unexplored, and is responsible for discharging into the Atlantic Ocean about 16% of the river water that is annually discharged into the world's oceans[47] (SRH, 2006). The importance of this region is such that the integrated actions for regional development are intended to be conceived as integrated into the basin, thus overcoming administrative boundaries, in order to solve conflicts of use especially related to the dichotomous interest of national/local development in the field of water and energy (SRH, 2006).

47 Moreover, about 84% of the territory is currently exploited for the extraction of natural food and mineral resources (SRH, 2006).

The process of implementing an active attitude towards the country's commitments under Agenda 2030 is still under construction. On the occasion of the High-Level Political Forum "Eradicating Poverty and Promoting Prosperity in a Changing World" organized by the United Nations in 2017, Brazil drew up its first voluntary report on the progress of Agenda 2030 (BG, 2017). The document presents figures about the correspondence between targets and indicators of the United Nations' sustainable development objectives and the multi-year plan (PPA)[48], and at the time of drafting the self-assessment report, 86% of the targets and 78% of the indicators were matched by the Plan (BG, 2017). Despite the fact that Agenda 2030 has not yet been 100% assimilated by national action, the country tries to identify and evaluate its progress in terms of multidimensional poverty, underlining that it has achieved excellent results in the past decade, especially thanks to the *Bolsa Familia*[49] program, which has been expanded since 2011 by the *Brasil sem miseria*[50] (MDS, 2011). Brazil has, in fact, reached the goal of halving the number of people living below the poverty line of 1.25 U$ (PPP), bringing them from 16.2% of the population in 1990 to 4.7% in 2009 (UN, 2015). However, according to the 2017 self-assessment document, due to the crisis from 2015, the population below poverty has returned to growth, fluctuating between 6.5% and 7.8% of the total population, drawing attention to the need for government integrated intervention to fight this multidimensional phenomenon (BG,2017).

48 The Pluriannual Plan (PPA) is the main instrument for medium-term planning of government actions, which must be carried out by law. It identifies the measures, expenditures and objectives to be followed by the government over a period of four years. The second year of a government term is valid until the end of the first year of the next term
(available at: http://www2.camara.leg.br/orcamento-da-uniao/leis-orcamentarias/ppa)

49 The *Bolsa Família Program* (PBF) is a conditional cash transfers (CCTs) program that benefits families living in poverty and extreme poverty throughout the country. The PBF has been created in October 2003 by the first Lula government and has three main axes: income transfer, conditionalities and complementary actions and programs. The transfer of income promotes the immediate relief of poverty. Conditionalities reinforce access to basic social rights in the areas of education, health, and social assistance. The complementary actions and programs aim at increase the development of families, so that the beneficiaries can overcome the situation of vulnerability.

50 The *Brazil sem miseria* (BSM) has been launched in June 2011 to complement the *Bolsa Familia*. It is a plan which adress families living with a family income of less than R $ 70 per month per person. In addition to the objectives of the *Bolsa Familia*, it adds the objective of productive inclusion, that is, the improvement of skills and cpabilities in order to expland the job opportunities and therefore the income among the poorer families (both in urban and in rural areas). This plan includes other programmes such as *Água para todos* (aimed to enlarge the access to water) and *Luz para todos* (aimend to enlarge access to energy).

1.2. Energy and development: a brief literature review

There is a wide range of literature using energy consumption as a proxy for energy/electricity use to verify its impact on economic development, which is different from human development in most cases. Apergis and Payne examine the impact on economic growth of renewable (2010, 2011a, 2012) and non-renewable (2012) energy consumption on various control groups (e.g. low, middle or high income countries) (2011). However, Apergis et al. (2016) propose a focus on hydropower, estimating the relationship between energy consumption (expressed as total hydroelectric consumption per capita in Kwh) and economic growth (expressed as GDP per capita). For the period 1965-2012, the 10 largest electricity consumers, including Brazil, were analyzed, together accounting for about 64% of world consumption. In fact, in addition, to recognize the importance of hydropower in the international approach to environmental policies, the author also admits that the previous works that compared the performance of renewables as a unitary block did not facilitate the application of specific energy policies. Through a non-linear panel smooth transition vector error model, already used in previous works (Apergis and Payne, 2012) the authors verify two different relations for the short and long run. In the long run, there is a positive unidirectional relationship from GDP per capita to hydropower consumption, with an elasticity of 0.526. However, in the presence of structural breaks[51] (linked to policies in specific countries), they note that since the structural break identified in 1988 the causal effect has been no longer unidirectional, but also has operated significantly and positively from hydropower consumption to economic growth. In fact, it can be said that up to a certain point the economic growth promotes the transition to new energies that in turn can be transformed into tools for growth. This last result is very interesting for the study of the Brazilian case if we remember that four years before the break the Tucuruí hydroelectric power plant came into operation, whose objective was to strengthen the GDP, being a project linked more to the industrial policies of the time than to the issue of access (Magalhães, 1987). According to Apergis et al. (2016), in correspondence with the other structural breaks in 2000 and 2009, the two-way relation is confirmed and indeed becomes even more intense, in support of the fact that economic intervention in the field of energy would generate a spillover effect in terms of

51 E.g. the introduction of renewable portfolio standards in the U.S. in 2000, the completion of the Three Gorges dam in China in 2000 or the completion of the Tucuruí dam in Brazil in 1988.

growth and *vice versa*. However, it is not tested whether the same spillover effect demonstrated by Apergis et al (2016) would also affect development. To do this it would be necessary to make a similar model testing the impact of hydropower on an indicator of human development (e.g. HDI). In this case, it should be useful to measure electricity use in terms of access rather than consumption.

Magnani and Vaona (2012) state that access to energy is a central aspect of development not only from an economic point of view since energy services are associated with social benefits. For this reason, they test which socioeconomic variables (e.g. rents from natural resources as a percentage of GDP, the percentage of the rural population and also the completion rate in lower secondary schools) affect access to energy on a panel data of 31 countries. This time they do not include Brazil. The main findings are that renewable resources (with the exception of hydropower[52]) often make access to energy services more feasible. On the other hand, hydroelectricity has a negative impact on development and also total revenues from the use of natural resources show an inverse and significant relationship with it. With the exception of small hydropower plants, hydropower plants are designed to supply large urban centers connected to the transmission grid rather than rural off-grid areas, the so-called *mercado disperso*, so that revenues from the use of water source equipment are not equally re-distributed locally in terms of access to energy services (Lemos, 2004). Therefore, in support of this new perspective, estimates confirm that GDP's influence on energy access loses strength, while policy interventions and the quality of institutions gain importance. Although Brazil is not included in the 31 countries that make up the panel, the conclusions that the authors draw from them seem to be interesting for the specific case of an emerging country: in order to facilitate access to energy, it is necessary to target mainly rural areas regardless of the attractiveness of demand on investments, so that the exploitation of natural resources is accompanied by policy interventions aimed both at protecting the endowment of resources and at promoting the conscious and participatory implementation of the electrification processes of the territory.

52 By the use of the word hydropower we always refers to large plants (installed capacity >30Mw). It is quite common in the literature to include small plants (installed capacity >1 and ≤ 30) or self-production plants (installed capacity ≤ 1) among the “other renewables" (the Tucuruí hydroelectric plant has an installed capacity of 8,370 Mw) (ANEEL, 2017)).

Kileber and Parente (2015), in relation to electricity production, raise the issue of the *endowment trap*[53] in low and middle-income countries where one of the most widespread sources of energy is hydropower. According to the *energy ladder theory*[54], the unidirectional relationship between GDP and renewable sources would lead each country to improve over time its energy matrix in the environmental sense, however the speed of this change is influenced by the availability of resources (endowment) that can lock a country into a trap even in the presence of high levels of GDP. Brazil, one of the first producers and consumers of electricity in the world, managed between 1970 and 2010 to differentiate its energy matrix by avoiding the endowment trap of hydroelectric power. According to Kileber and Parente (2015), the share that each energy source has in the Brazilian energy matrix depends on three factors: GDP, the available reserve of primary resources and the quality of governance. These factors act jointly and in different amounts for each type of source. In Brazil, the presence of one of the largest hydrographic basins in the world induced the electrical matrix to be extremely dependent on hydropower. The large availability of water resources generates a reduction in the unit cost of electricity production such that, even with the increase in GDP, the country could not found it convenient to move to new energy sources, limiting its environmental performance and at the same time exposing itself to the risk of natural shocks (such as floods or droughts) that would be avoided by diversification. However, the threat of a resource trap seems to have escaped. In fact, on the one hand, the pressure of increasingly conscious public opinion and the actions of non-governmental bodies to protect the environment and minorities affected by the negative effects of hydroelectric power plants have helped to limit the relative share of the source into the energy mix (which has, however, continued to increase its installed capacity in the last 30 years) (EPE, 2017). In addition, government incentives for alternative energy production have also contributed to increase the relative share of alternative sources on the matrix (EPE, 2017). It is important to note that, according to EPE, between 2015 and 2016 the relative share of hydro in the Brazilian electricity matrix started again to rise, after a decade of slow and progressive reduction (EPE, 2017).

53 In the field of energy economics, when the large availability of natural resources (e.g. water) discourage investment in alternative sources, and a country's economy remains highly dependent on its endowment.

54 The theory according to which the economic growth of a country is followed by the evolution of the energy mix that supports it.

In support to this, some researches exploring energy access in relation to other socioeconomic variables (additional to per capita GDP or per capita income) are based on case studies found in Africa and specifically in sub-Saharan Africa. For example, Onyeji et al. (2012) explore the significant and negative relationship between poverty and rural electrification, pointing out that rural electrification is positively correlated with the availability of funding and population density. Nanka-Bruce (2010), on the other hand, do a regression of the percentage of the population with access to energy on the human development index, with the result of obtaining a significant and positive estimate of its coefficient. In line with the authors cited, Van Els et al. (2012) in reference to the issue of electrification in the Brazilian Amazon calls for a change of approach that should not be that of simple electrification, but that of rural development, in accordance with what stated by Magnani and Vaona (2012).

2. Exploratory Analysis of the data – Principal Components Analysis on the case of Pará

The role of hydroelectric energy in boosting the economic growth of nations has been empirically demonstrated in the literature. However, in the light of the capability approach (Sen, 1998), the income wealth deriving from growth does not necessarily coincide with well-being. In fact, considering income as a means to an end, lack of access to water or energy, as well as inequality in the distribution of incomes, are important adverse conversion factors: the former, because it limits the ability to transform income into functionings[55], the latter because it induces deprivation in terms of capabilities[56].

In 2013, the United Nations Development Program (UNDP), together with the Fundação João Pinheiro (FJP) and the Instituto de Pesquisa Econômica Aplicada (IPEA), published the *Atlas of Human Development in Brazil*. In this report, they propose to measure human development on the basis of income, long and healthy life and knowledge, the same methodologies used by

55 Being and doing activities that people "value and have reasons to value"(Sen, 2000). So functioning relate to many different dimensions of life – including survival, health, work, education, relationship, empowerment, self-expression and culture.

56 The freedom to enjoy valuable functionings (Sen, 2000).

the UN at the country level. This calculation methodology is adapted to create a Municipal Human Development Index - MHDI, similar but not comparable with the Human Development Index - HDI, in order to evaluate achievements at a smaller level of dis-aggregation (i.e. the municipalities level).

The variables used to build the MHDI are:

Per capita income (Y_pro_cap): Classic indicator of per capita income, is the ratio between the sum of the income of all individuals living in permanent private households and the total number of these individuals (per month, indicated in Brazilian real (BRR$) of 1 August 2010 (UNDP, FJP, IPEA, 2013).

Life expectancy at birth (ESPVIDA): In line with OECD and UN, the indicator is calculated as the average number of years a person is expected to live from birth if the level and age-specific mortality rate prevailing in the year of the Census remains constant throughout her life (UNDP, FJP, IPEA, 2013).

Human development index of education (Edu): measured by two indicators. On the one hand, it considers the schooling of the adult population as measured by the percentage of people aged 18 years or older who have a full fundamental education (this dimension is weighted 1). On the other hand, it takes into account the school flow of the young population measured by the arithmetic mean of the percentage of children aged 5-6 attending school, the percentage of children aged 11-13 attending the last years of fundamental education, the percentage of children aged 15-17 with full fundamental education and the percentage of people aged 18-20 with full basic education (this dimension is weighted 2). As it accompanies the school-age population at four important stages of their education, this makes it easier for managers to identify whether children and young people are in the right series at the right ages (Figure 3). The geometric mean of these two components is nothing more than IDHM Education (UNDP, FJP, IPEA, 2013).

However, from the capability approach point of view, the concept of human development is still more complex than its municipal index. It is for this reason that we insist on recalling the importance of taking into account the variables of access and inequality when trying to measure a socioeconomic performance of the 143 municipalities of the state of Pará within the context of the Brazilian development process (Brand-Correa and Steinberger, 2017).

Figure 3. Taxonomy of the education series in Brazil

Education system in Brazil	
Nursery	0-3 years
Pre-school	4-6 years
Base	6-17 years
Fundamental (primary & secondary school)	6 - 14 years
Medium (high school)	15 - 17 years
Higher (University)	18-24 years

Source: Law n°9.394 December 20th of 1996.

Thus, in addition to these variables, we propose to take into account the access variables and the inequality index:

Access to water (T_AGUA): is the percentage of the population living in households with piped water calculated as the ratio between the population living in permanent private households with piped water (with pipes in one or more rooms) and the total population living in permanent private households multiplied by 100. Water can come from the general network, well, spring or reservoir supplied by rainwater or tankers (UNDP, FJP, IPEA, 2013).

Access to electricity (T_LUZ): is the percentage of the population living in households with electricity, calculated as the contribution between the population living in permanent households with electric lighting and the total population living in permanent households multiplied by 100. Lighting is considered as coming from a general network, with or without the counter (UNDP, FJP, IPEA, 2013).

Inequality index (GINI): is expressed by the Gini index that measures the degree of inequality in the income distribution among individuals based on per capita household income. Its value varies from 0 when there is no inequality (the family income per capita of all individuals has the same value) to 1 when the inequality is maximum (only one individual has all the income). Refers to those living in permanent private households (UNDP, FJP, IPEA, 2013).

At this point, having collected a dataset of six variables (proxies of well being) observed on 143 units, it may be useful to conduct an exploratory analysis moving in a double direction (Albuquerque, 2004). On the one hand, we want to reduce the number of variables without losing information (to simplify any policy advice), and on the other hand, we want to identify if there is a pattern of data and what it is. In order to achieve both objectives, the Principal Component Analysis - PCA is applied (Pearson, 1901; Hotelling, 1933). Through the PCA we want to extrapolate from the data matrix a simpler structure underlying the data with the idea of finding a new reference system in order to maximize the variance of the variables represented along the axes. Practically the PCA allows us to reduce the set of $k=6$ variables observed on 143 units, to a smaller set of unrelated artificial variables $p<k$ that still retains most of the information contained in the original larger set. The PCA is based on the fact that any set of original k quantitative variables can be transformed into a set - of the same size - of unrelated k variables (called principal components), each of which is a linear function of all the original k variables. The new set contains the same information as the original set, while the k variables are such that the first new component (i.e. Comp.1) accounts for as much of the variability in the data as possible and each subsequent component accounts for as much of the remaining variability as possible. At this point, the objective of size reduction is obtained by choosing for the purpose of analysis the first $p<k$ main components (e.g. Comp.1 and Comp.2), that is only those that contain most of the variability, i.e. as much information as possible. There is no rule for the choice of the main components. In fact, selection is made on the basis of the seek for a balance between the number of components chosen and the variability they account for. That is, it is desirable that the main components are as few as possible - compared to the number of initial variables - while at the same time they explain as much variance as possible. The interpretation of the components is complicated by the fact that each component is a mixture of the original variables; however, the comparison between the units is simplified by the fact that the values associated with the components are ordinal values. It is then necessary to give an economic meaning to the chosen components, and this can be done by looking at the correlations between the components and the original variables (Smith, 2002).

Taking into account the 143 municipalities of the Federal State of Pará, we will carry out the PCA for 1991, 2000 and 2010, which are respectively the years in which the last three censuses were conducted. For each year we will take into account the Comp.1 because it well accounts for both the dimensions contained in the municipal human development index and the additional dimensions considered. On the basis of the correlations (Figures 4, 5, and 6) we can say that Comp.1 has always a strong and positive correlation with the income, education, health and with the accesses to water and energy. Comp.1 quite well accounts for the original variables in each of the years considered (all coef.≥|0.5|, except for the Gini index, which have the lowest correlation in absolute terms and also an ambiguous sign). Moreover, in order to enrich the analysis of the data, we are going to also consider Comp.2 and Comp.3 . In fact it is noteworthy that while education, access to water and access to electricity move in synchrony with the GDP per capita for all three years, inequality and life expectancy should be better accounted for by the second and third components respectively (Figure 4 and 5). Only in 2010 the meaning of this two component is reverted, that is, in 2010, it is Comp.3 that best accounts for life expectancy while Comp.2 better accounts for the aspect of inequalities. (Figure 6).

At this point, for the sake of simplicity, it is useful to divide the performance of any municipality in terms of well-being into just two factors (this procedure will be especially useful later for the graphical representation of the results): access to services represented by Comp.1 (which also accounts for health) and income inequality represented by Comp.2 (in 1991 and 2000) and Comp.3 (in 2010). In fact, Comp.1 provides a direct measure of well being through accesses, which means that Comp.1 increases as the accesses improve, while Comp.2 provides an inverse measure of inequality, which means that it increases in the presence of a reduction of inequalities[57]. Thus, in order to plot the results of the analysis in a two-dimensional space (handier than a three-dimensional plot), we are going to use Comp.1 (x-coordinate) and Comp.2 (y-coordinate) both in 1991 and in 2000. Taking in mind the interpretation of correlation above-mentioned, just in 2010, they-coordinate is represented by the Comp.3. With this choice, we renounce in all three years to represent the component that best accounts for life expectancy. In fact, the variable ESPVIDA is better captured by Comp.3 in 1991 and 2000 and by Comp.2 in 2010. However, we notice that even if with a lower coefficient in absolute value ESPVIDA is well captured by the Comp.1 itself, quite limiting the loss of information of our graphic analysis.

It is now possible to identify four quarters, each one indicating a different performance of the observed units. The axes of the biplot are the pair of principal components while the points and the vectors represent respectively the 143 municipalities under observation and the

57 In 2010, Comp.3 is a direct incicator of inequality since it increases in the presence of augmenting inequality

original variables. For each component there are two sets of axis scales: one relates to the values assumed by the component on the different units, i.e. the scores (the bottom one for Comp.1, and the left one for Comp.2); the other one relates to the coefficients of the linear function that identifies the component, i.e. the loadings (the top one for Comp.1, and the right one for Comp.2). Each vector direction (with respect to the axes) shows the sign of the correlation of the corresponding original variable respectively with Comp.1 and with Comp.2 (Smith, 2002). According to Figure 7 in the north-east quarter, there are the municipalities that have shown the best performance in terms of both access and reduction of inequalities (Comp.1>0 and also Comp.2>0). In the south-west quarter, on the other hand, the worst municipalities are located, with Comp.1<0 and also Comp.2<0. In the two remaining quarters there are those municipalities that are lacking in only one of the remaining observed dimensions, and in particular, in the north-west quarter, there are those municipalities with access problems (Comp.1<0), while in the south-east quarter there are those municipalities that have problems in terms of reducing inequalities. Notice that in 2010 Comp.3 is considered instead of Comp.2, therefore the interpretation of the quarters needs to change, that is, the best performance is achieved with Comp.1>0 and Comp.3>0 while the worst one is given by Comp.1<0 and Comp.3>0. The other two quarters will show lack of accesses (Comp.1<0 and Comp.3<0) or lack in inequality reduction (Comp.1>0 and Comp.3>0). Notice that evidence from the interpretation of the graph should refer to the relative position of each unit with respect to the other units of the sample.

At this point, focusing on the micro-region of Tucuruí, one is able to observe the socioeconomic achievements of an area affected by the presence of a hydroelectric plant. The micro-region of Tucuruí is composed of the twelve municipalities surrounding the biggest hydroelectric plant in Brazil. The case of the Tucuruí power plant is a good example since its effects reach municipalities both upstream (i.e. Breu Branco, Goianêsia do Pará, Itupiranga, Jacundá, Nova Ipixuna and Novo Repartimento) and downstream (Baião, Cametá, Igarapé-Miri, Limoeiro do Ajurú, Mocajuba), in addition to the hosting city of Tucuruí (EEMI, 2013). Starting from a descriptive analysis is interesting to raise the doubt of whether or not and to what extent a hydroelectric plant beside boosting the national GDP growth, has some impacts on human development at the local level (Lemos, 2004). The relevance of this case study is even greater if we take into account the fact that in the city of Belo Monte, in the Xingu basin, a project similar to that of Tucuruí is likely to repeat the same errors, even though the past lessons (Pinto, 2012).

On the basis of the correlations in 1991 (Figure 4) we define Comp.1 as a direct indicator of access and Comp.2 as an inverse indicator of equality, while Comp.3 better accounts just for life expectancy. Comp.1 (55%) and Comp.2 (18%) together account for 72% of the variability of the data, therefore by plotting them is it possible to assess the performance of the 12 municipalities of the micro-region of Tucuruí in terms of both accesses and inequality. It is worthy to note that discarding the Comp.3 from the graphic analysis does not seriously affect the information since life expectancy is still captured by Comp.1 (although its correlation is lower than that presented with Comp.3)(Figure 4). Looking at the Figure 8, it is possible to note that in 1991 8 out of 12 municipalities of the micro-region of Tucuruí have problems of access, 4 of which are also suffering from inequality (worst performance). Only 3 municipalities, including Tucuruí - the headquarters of the hydroelectric power plant - have a satisfactory performance in both indicators (best performance) (Figure 7).

In 2000 Comp.1 (53%) and Comp.2 (20%) together account for about 73% of the variability of the data. On the basis of the correlations illustrated in Figure 5, we define Comp.1 as an indicator of access and Comp.2 as an indicator of equality, while Comp.3 better accounts for life expectancy, in the same way as for 1991. In fact, with slightly different values, plotting the correlations only considering Comp.1 and Comp.2 reproduce the a plot quite similar to that already commented for 1991 (Figure 9). It should be noted, however, that in 2000 the number of municipalities upstream or downstream the hydroelectric plant with the best performance reduced themselves by one while there is one more unit performing worst. The number of municipalities whit either lack of access or inequality remains the same (Figure 7).

Finally, on the basis of the correlations in 2010, we define again Comp.1 as an access indicator. However, this time, Comp.3 better accounts for inequality while Comp.2 better accounts for life expectancy (Figure 6). In line with what we have done in previous years, we make a plot to analyze the performance of target municipalities with respect to access and inequality. Therefore, we will consider Comp.1 as far as access is concerned, and Comp.3 as a direct indicator of inequality. In fact, the Comp.3 presents a positive correlation with the GINI index, to indicate that it increases as the GINI index increases, and decreases *vice versa*. Comp.1 (53%) and Comp.3 (20%) together account for about 66% of the variability. In this case, the quarters of the two-dimensional plot must be redefined: the best performances are found in the south-east quarter (Comp.1>0 and Comp.2<0) and the worst performances in the north-west one (Comp.1<0 and Comp.2>0). Municipalities with only access problems will have both negative components (south-west quarter) while those with only inequality problems will have both positive components (northeast quarter) (Figure 10). Compared to 2000, the number of units among the best performances in 2010 remains the same, however, this not positive result is mitigated by the fact that the number of units with worst performances is reduced by one (Figure 7). On the other hand, the slight reduction in the number of municipalities with only access problems would be a good result if it was not accompanied by the doubling of those that, while solving the access problem, present a worse situation in terms of inequality (Figure 7). If we even take into account the changes over the entire period under consideration, we can say that those with good access are reduced from 4 to 2, but those with inequality problems go from 1 to 4 (Figure 7). The most striking example is precisely that of the municipality of Tucuruí, which passes from quadrant A to quadrant C due to inequalities. The move of the municipality of Tucuruí is also responsible for the reduction of the units with best performance in the twenty years considered, whereas the number of units with the worst performance remain practically unchanged (Figure 7).

Figure 4. Principal components correlations in 1991

	T_AGUA	T_LUZ	Y_pro_cap	Edu	ESPVIDA	GINI
Comp.1	0,871	0,828	0,772	0,879	0,518	0,438
Comp.2	0,272	0,353	-0,389	0,306	-0,377	-0,692
Comp.3	0,056	0,197	-0,010	-0,050	-0,739	0,509

Source: Personal elaboration from UNDP, FJP, IPEA, 2013

Figure 5. Principal components correlations in 2000

	T_AGUA	T_LUZ	Y_pro_cap	Edu	ESPVIDA	GINI
Comp.1	0,889	0,853	0,730	0,882	0,564	0,221
Comp.2	0,232	0,261	-0,476	0,270	-0,239	-0,834
Comp.3	0,078	0,290	-0,140	0,118	-0,741	0,443

Source: Personal elaboration from UNDP, FJP, IPEA, 2013

Figure 6. Principal components correlations in 2010

	T_AGUA	T_LUZ	Y_pro_cap	Edu	ESPVIDA	GINI
Comp.1	0,778	0,861	0,777	0,883	0,498	-0,453
Comp.2	0,210	0,280	-0,490	0,046	-0,675	-0,601
Comp.3	0,349	0,175	0,119	0,008	-0,471	0,635

Source: Personal elaboration from UNDP, FJP, IPEA, 2013

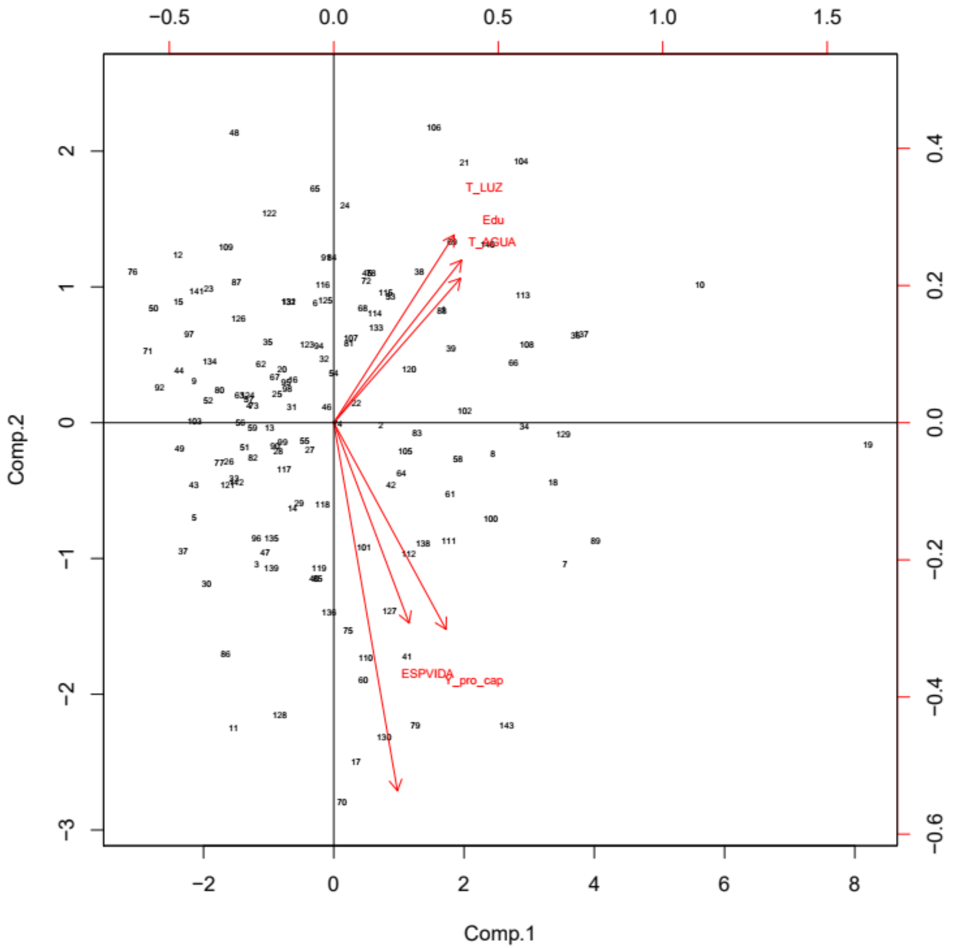
Figure 7. PCA scores

Location	ID	Name	1991	2000	2010
Upstream	27	Breu Branco	D	D	A
	51	Goianésia do Pará	D	C	C
	59	Itupiranga	D	D	D
	61	Jacundá	C	C	C
	77	Nova Ipixuna	D	D	C
	80	Novo Repartimento	B	D	D
Downstream	16	Baião	B	D	A
	32	Cametá	B	B	D
	54	Igarapé-Miri	A	B	B
	63	Limoeiro do Ajuru	B	B	B
	72	Mocajuba	A	A	D
Plant	137	Tucuruí	A	A	C
Scores			freq_1991	freq_2000	freq_2010
A (Comp.1>0; Comp.2>0)		Best performance	3	2	2
B (Comp.1<0;Comp.2>0)		Halfway results (1)	4	3	2
C (Comp.1>0:Comp.2<0)		Halfway results (2)	1	2	4
D (Comp.1<0; Comp.2<0)		Worst performance	4	5	4

Note: in 2010 we use Comp.3 instead of Comp.2. Moreover, in 2010 the score are assigned on the basis of a modified criteria: A(Comp.1>0; Comp.3<0), B(Comp.1<0; Comp.3<0), C(Comp.1>0; Comp.3>0), D(Comp.1<0; Comp.3>0).

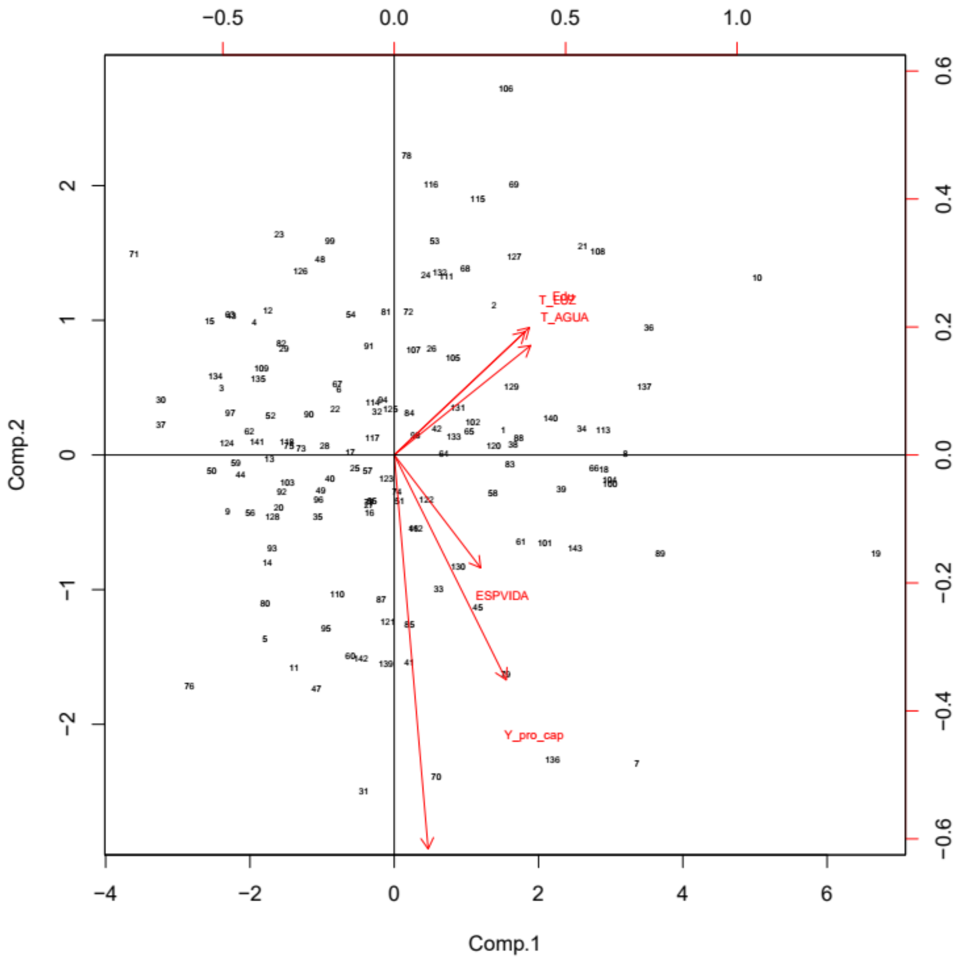
Source: Personal elaboration from UNDP, FJP, IPEA, 2013

Figure 8. PCA – biplot 1991



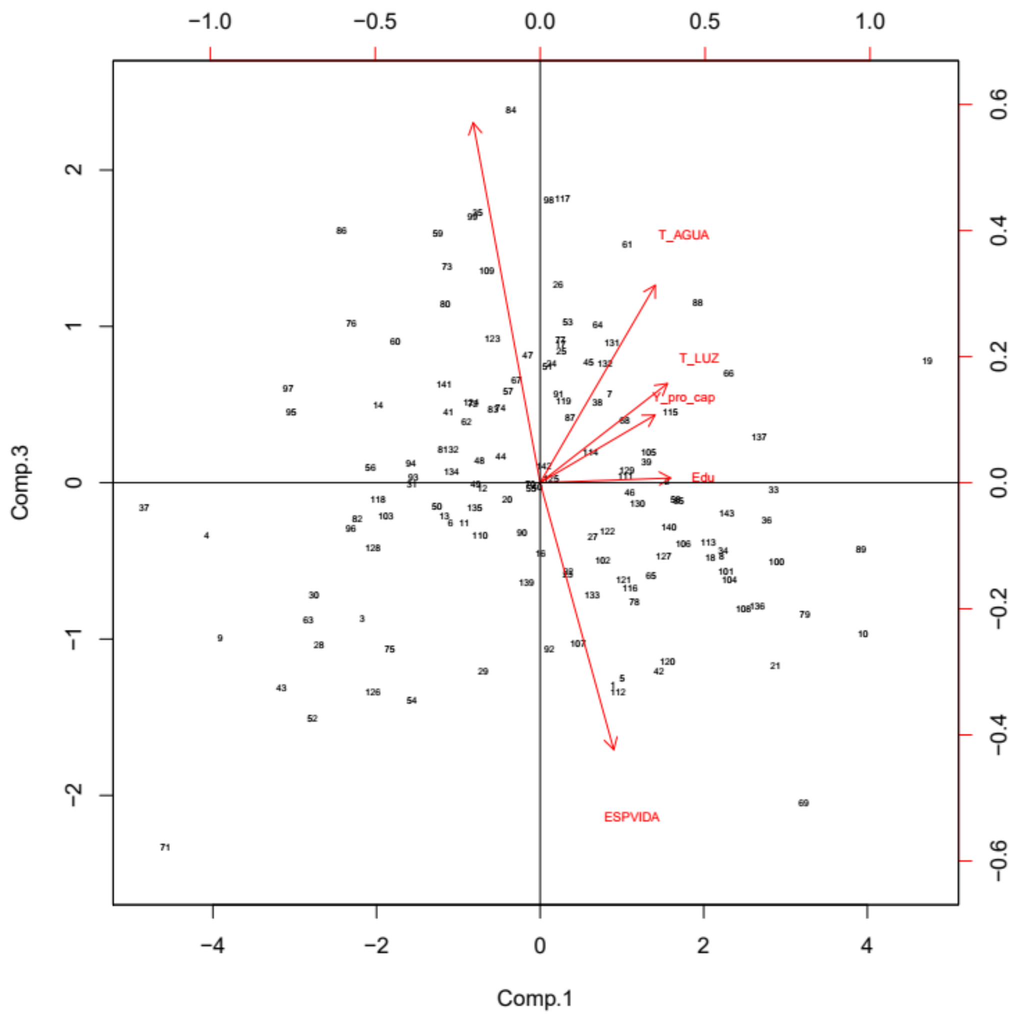
Source: Personal elaboration from UNDP, FJP, IPEA, 2013

Figure 9. PCA – biplot 2000



Source: Personal elaboration from UNDP, FJP, IPEA, 2013

Figure 10. PCA – biplot 2010



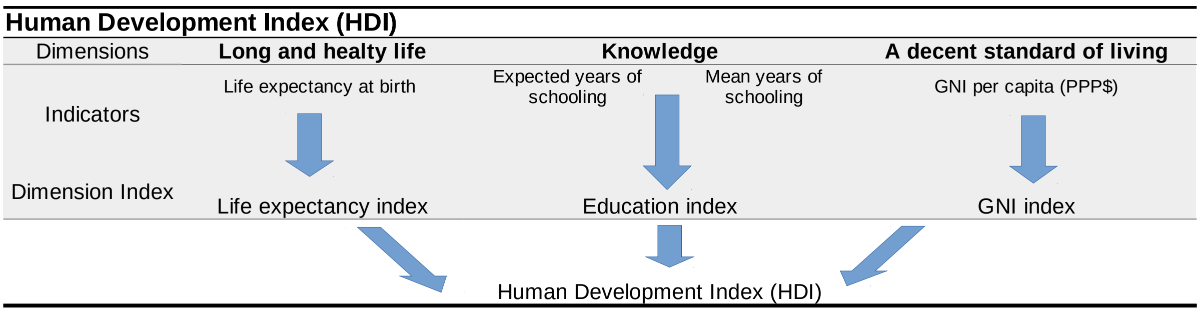
Source: Personal elaboration from UNDP, FJP, IPEA, 2013

3. How to measure human development from an access perspective

3.1. Attempts to measure human development: a brief literature review

The first universal definition of human development dates back to 1990 when the United Nations published its first Human Development Report (UN, 1990). The need for a re-definition of development arises from the criticism, claimed mainly by Sen (1983, 1988), at the use of the GDP as a too reductive measure of the development of a country. In fact, what emerges from the first report on human development of 1990 is first of all the redefinition of development that for the first time is defined as a human development that is able to create an environment that allows people to enjoy a long, creative and healthy life in which income and economic growth play a fundamental role as a means rather than an end (Anand and Sen, 1997). In this theoretical context, in 1996 the Human Development Index (HDI) was calculated for the first time, expanding the information given by the simple GDP by means of two more dimensions. In fact, the HDI measures the achievements of nations in three key areas such as a long and healthy life, access to education and a decent standard of living. To do this, it uses the normalized geometric mean of three indicators i.e. life expectancy, the average of years of study expectancy and the average of years of schooling, and GDP per capita (Figure 11).

Figure 11.HDI methodology



Source: Personal elaboration from UNDP

The human development index is very compact and so useful for comparisons between countries. The United Nations has begun to calculate it with a twofold objective: on the one hand, to recognize that income and GDP per capita are not direct indicators of the standard of living of nations, on the other hand, to construct an indicator that would allow a cross-country comparison given the number and the heterogeneity of countries that were included in the UN organization at the time of the publication of the first United Nations Development Report[58]. However, the HDI has been criticized for its non-inclusiveness, which, while considering long and healthy life and knowledge, is still a victim of the impossibility of really capturing all the variables that contribute to shaping development in practice. Integrating the analysis of development with further socioeconomic or environmental variables can be a useful tool to improve the indication of policy in the direction of increasing well-being. Therefore, the United Nations itself has enriched the range of indicators - complementary to both GDP and HDI - such as the Capability Poverty Measure (CPM) which measures the lack of basic capabilities, the Gender Empowerment Measure (GEM) which measures the absence of gender inequality or the Human Poverty Index (HPI) which measures deprivation in the same dimensions as they are included in the HDI, making a difference between developed and developing countries. This approach has given rise to new criticisms since there are too many indicators to take into account when comparing countries or making policy decisions.

In order to overcome the new problem, in 2011 the OECD, following a bottom-up approach proposed, a multidimensional index of well-being, i.e. the Better Life Index, which is built on the perceptions of users in the various countries that contribute to building a national framework in each of the 11 dimensions considered. In this case, however, the exhaustiveness does not make the comparison so easy, since a country can differ from another in any of the 11 dimensions, not allowing a fair comparison. This index, therefore, in addition to being limited by the statistical non-significance of the sample that contributes to its construction, is undoubtedly a very unwieldy tool for targeted policy interventions are given a large number of dimensions included.

We can say, in general, that the need to obtain a multidimensional and inclusive measure that is both compact and easy to use in policy making remains unfulfilled. However, the literature is rich in attempts to apply methodologies for the inclusion of further dimensions within the

58 The first UNDR (1990) was published when the United Nations had 159 members.

HDI through an adjustment process, justified from time to time by the relative theoretical bases. In 2010, the same United Nations proposed an HDI adjusted to inequalities, starting from the idea that it is necessary to know the distribution of achievements among the population for the index of human development to be truly reliable. This index is nothing more than an arithmetic average of the three dimensions already contained in the HDI, each of which is adjusted to the inequalities (Alkire and Foster, 2010).

Focusing to European countries, in 2005 Monni and Costantini (2005) proposed a Sustainable HDI to respond to the renewed extended approach that wants development to be achieved by allowing future generations to preserve not so much the stock of capital (Solow, 1991), but the ability to produce wealth , thus claiming to capture further dimensions in terms of capabilities that are ignored in both GDP and HDI (Anand and Sen, 1997). The authors, starting from the Generalized Human Development Index, introduce the environmental dimension (through an indicator of the quality of the environment and another of the access to resources) and the social dimension (i.e. social stability). Specifically, it is interesting to note that the GNI used in the HDI is here replaced by the GNNP i.e. an alternative formulation of the GNP in which the exploitation and depletion of the natural resources associated with the level of GNI are taken into account, considered the natural resource as a means to the end.

Carefully assessing the pros and cons of using a myriad of specific indices instead of composite indicators and in the light of the results of the exploratory analysis presented in paragraph 2, it is interesting to present in the next article a methodology for the inclusion of the dimension of access to natural resources, as a determining factor of development, within the human development measure at the municipality level. It should be noted that the approach used in the next paragraph, while addressing the issue of access to natural resources, differs both methodologically and theoretically from that presented by Monni and Costantini (2005).

3.2. Building a new indicator

As already mentioned, the literature in terms of human development is studded with the presence of a myriad of composite indices, each with the aim of capturing as many development variables as possible. However, it is clear that the increase of the information contained in an index reduces its efficiency. In fact, its practical use becomes complex both in terms of comparison (comparable cross-data) and for the identification of specific policies (in the presence of composite indices it is difficult to understand in which dimension to intervene). According to Booysen (2002), there are some fundamental criticisms to be made of multidimensional indices. Among these, first of all, there is the risk of excluding variables that would have an important role in describing the phenomenon. Secondly, the performance of every single dimension is not easily observable, but the units observed, e.g. the countries, are compared on the basis of the total value of the composite index. Finally, the techniques used to weigh each indicator are arbitrary e.g. vary from country to country, and therefore may be criticized for influencing the final index measurement unduly. Therefore, the aim here is to identify an alternative indicator to MHDI, which allows one capturing some additional dimensions that are fundamental for the measurement of development, and at the same time allows to solve the problems indicated by Booysen (2002). Starting from the exploratory analysis carried out in the second paragraph, we are now working on measuring the municipal development of the municipalities of the state of Pará. The dimensions that are supposed to be included are access to water and access to energy, meaning the access of final consumers - unlike Monni and Costantini (2005). The issue of inequality is temporarily left aside.

Then, taking as a reference the results of the analysis of the principal components presented in paragraph 2 and considering the structure of Comp.1 (see Tab.3,4 and 5), we choose here to consider Comp.1 as a new Municipal Human Development Index adjusted for accesses. In fact, Comp.1 is constructed by adding to the three variables included in the MHDI (income, life expectancy at birth and human development index of education) two components of access: access to water and access to energy. In the PCA, Comp.1 explains - on average for the three years - more than the 60% of the variability of the selected data and is strongly correlated to the access variables (see Tab.3,4 and 5). This Municipal Human Development Index adjusted for accesses also allows us to respond quite satisfactorily to the criticisms of composite indices:

1. It reduces the omission of important variables (i.e. it includes all the dimensions present in the MHDI calculation and also the additional access variables).

2. It is not subject to arbitrary methods of calculation and weight of the individual dimensions since each of them explains Comp.1 on the basis of the correlations resulting from the PCA[59].

3. There are no problems of comparison deriving from methodological differences because Comp.1 assigns to each observed unit an ordinal value (rank) and not a value between 0 and 1 as is the case for the MHDI.

At this point, considering the Comp.1 as an alternative Municipal Human Development Index adjusted for access, we proceed in ordering the municipalities both on the basis of the MHDI and on the basis of the Comp.1. In this way, as in Luzzati and Gucciardi (2015) we can verify whether and to what extent the two rankings differ one from another.

First of all, Spearman's correlation index indicates that the two rankings are strongly correlated in all three years and that the correlation increases as the years go on (Figure 12). This increasing correlation over time also results from the reduction of the dispersion in the Figures 13, 14 and 15.

Figure 12. Spearman's correlation ρ

	Spearman's rank correlation rho		
	1991	2000	2010
ρ	0.817309	0.9070534	0.9213859
p-value	2.2e-16	2.2e-16	2.2e-16

Source: Personal elaboration from UNDP, IPEA, FJP, 2013

In 1991 all of the municipalities in the micro-region of Tucuruí had a worse ranking with the MHDI adjusted for accesses (i.e. Comp.1) than with the MHDI. The number of municipalities that worsen taking into account the accesses is more or less the same between the two areas close to the dam (i.e. 2 downstream municipalities and 3 upstream municipalities). On the other hand, of the six municipalities that improve their relative position, the municipalities upstream are twice as many as the municipalities downstream. Among those that improve their position, there is Tucuruí, which is considered as a municipality upstream (Figure 13).

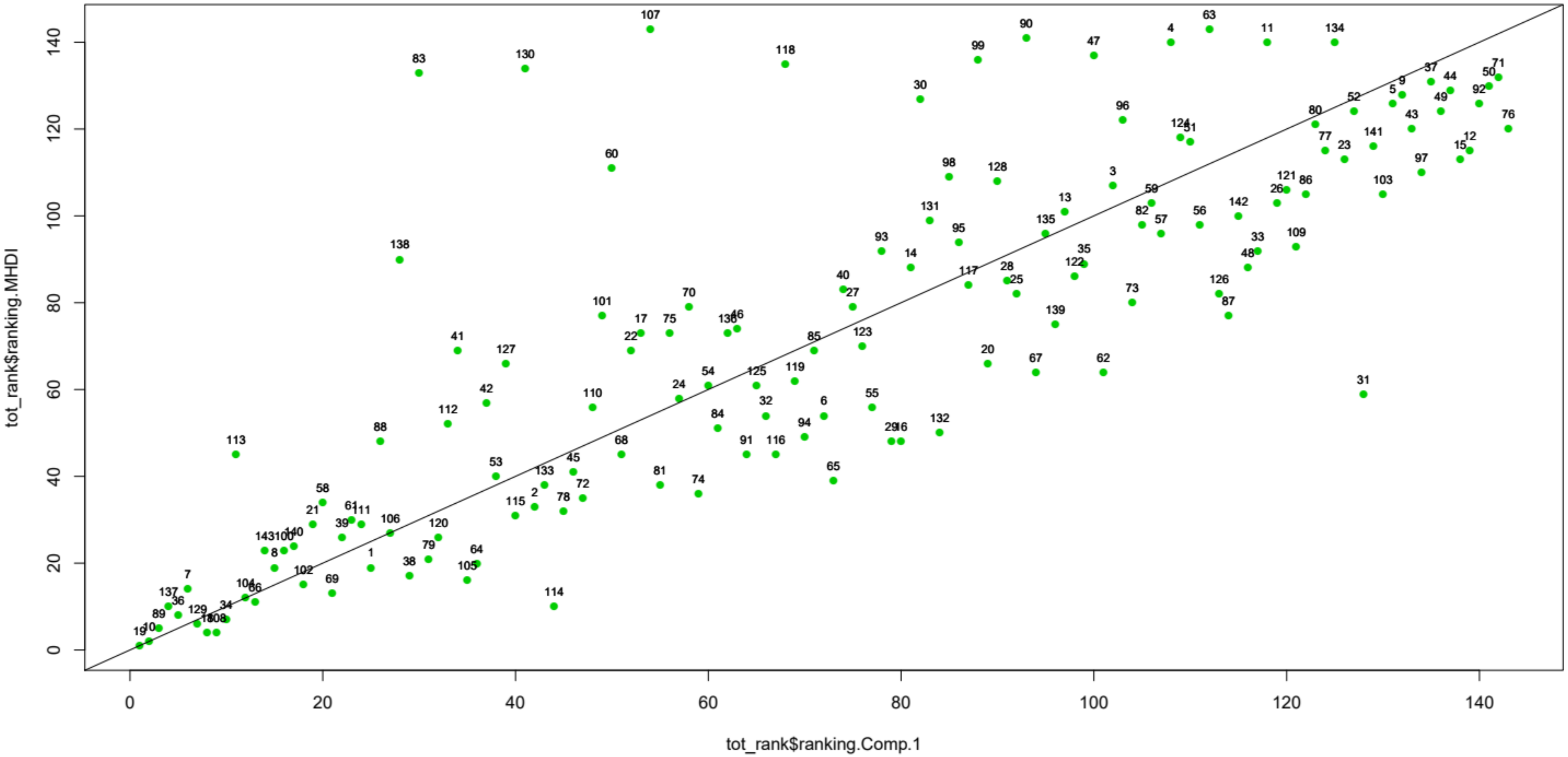
59 The weights for each principal component are given by the eigenvectors of the correlation matrix, or if the original data were standardized, the co-variance matrix (Vyas and Kumaranayake, 2006).

As in 1991, in 2000 no municipality maintained the ranking of the previous year. Among the six municipalities that improve their relative position when access is taken into account, there are four upstream municipalities (including Tucuruí) and just more two downstream municipalities (Figure 14).

Finally, in 2010 it is possible to note that for the municipality of Mocajuba there was no difference in ranking. However, this year only four municipalities are worsening their relative status, while most of them finally show a relative improvement in human development due to access. Three out of four of those that continue to worsen their position are in the downstream area. The positive result, however, is that eight out of twelve municipalities are improving their position, including almost all those in the upstream area (Figure 15). This result is positive but evidence suggests that there is an extreme slowness in the process of expanding accesses in an area, characterized by an abundance of water resources, which hosts the Country's main hydroelectric power plant. It is therefore difficult to establish whether it was the process of economic development in itself that led to the slow improvement of living conditions in the area (also through programs such as *Água para Todos* and *Luz para Todos*) or whether this is the timid and almost thirty years late result of the implementation of a big hydroelectric project.

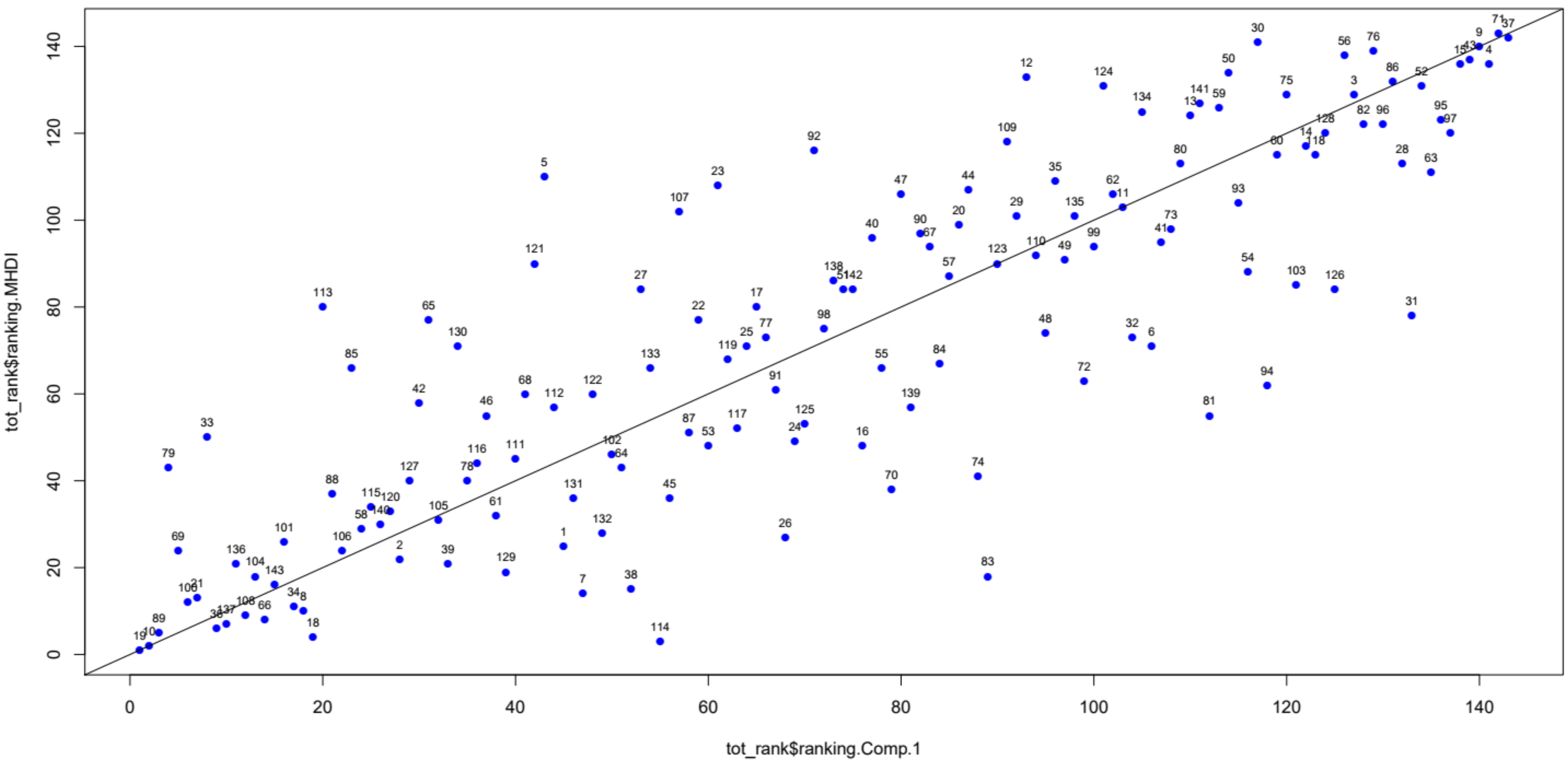
In conclusion, the analysis of the divergences between the MHDI ranking and the Comp.1 ranking provides a general assessment of the usefulness of Comp.1, which seems to be useful in representing different conditions in terms of access compared to what is indicated by the MHDI observation (Figure 16). If we consider the 12 municipalities of the Tucuruí microregion, it is clear that the results in terms of MHDI do not necessarily correspond to the same results in terms of access.

Figure 13. Ranks correlations in 1991



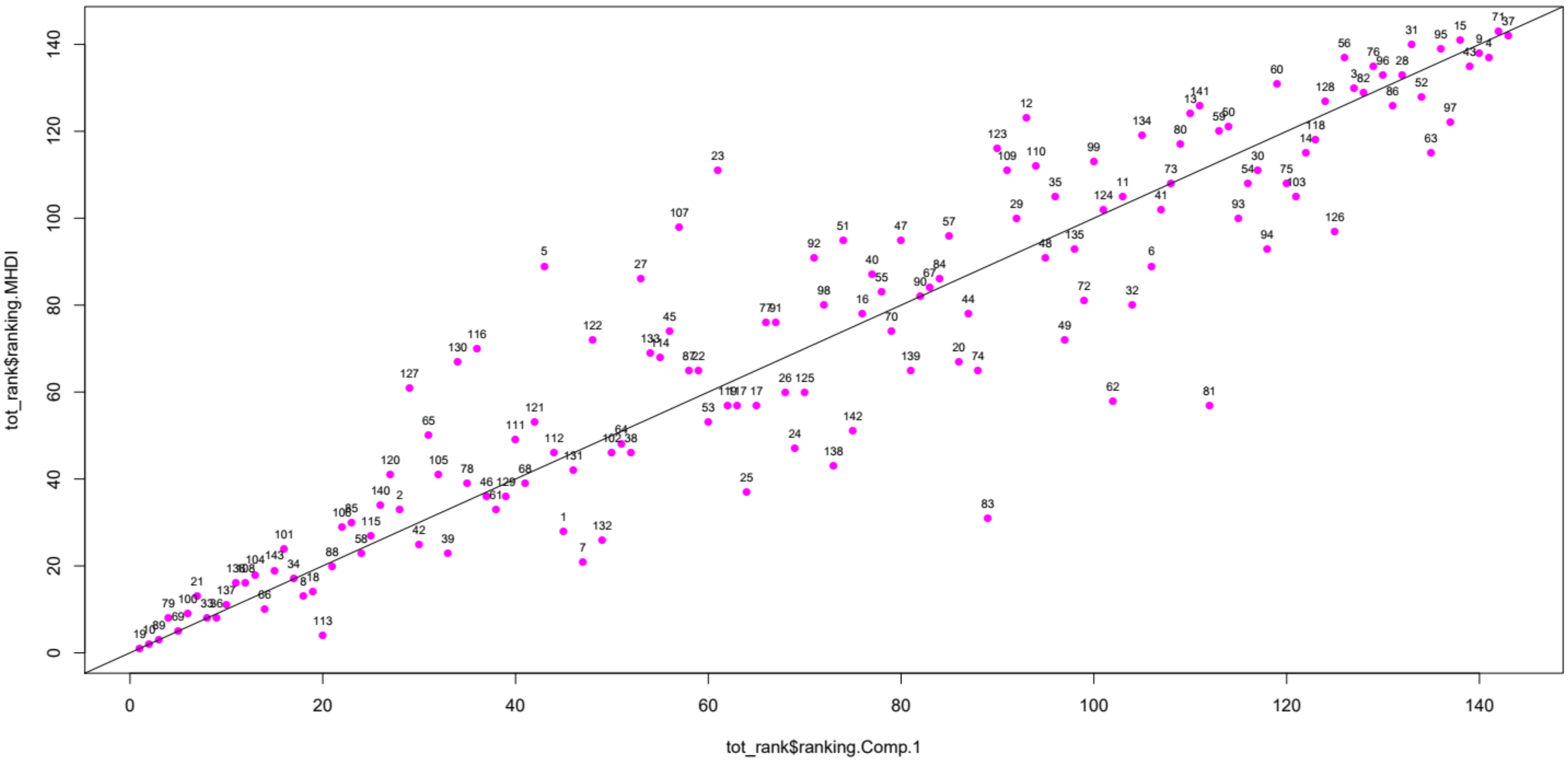
Source: Personal elaboration from UNDP, FJP, IPEA 2013

Figure 14. Ranks correlations in 2000



Source: Personal elaboration from UNDP, FJP, IPEA, 2013

Figure 15. Ranks correlations in 2010



Source: Personal elaboration from UNDP, FJP, IPEA, 2013

Figure 16. Rankings

		1991					2000					2010				
Code	Names	MHDI	rank_MHDI	Comp.1	rank_Comp.1	Δ	MHDI	rank_MHDI	Comp.1	rank_Comp.1	Δ	MHDI	rank_MHDI	Comp,1	rank_Comp,1	Δ
1	ABAETETUBA	0,386	19	1,68	25	6	0,501	25	1,51	30	5	0,628	28	0,89	45	17
2	ABEL FIGUEIREDO	0,357	33	0,72	42	9	0,508	22	1,38	31	9	0,622	33	1,55	28	-5
3	ACARÁ	0,254	107	-1,18	102	-5	0,35	129	-2,39	136	7	0,506	130	-2,17	127	-3
4	AFUÁ	0,025	140	-1,30	108	-32	0,33	136	-1,93	126	-10	0,489	137	-4,07	141	4
5	ÁGUA AZUL DO NORTE	0,208	126	-2,14	131	5	0,376	110	-1,79	122	12	0,564	89	1,00	43	-46
6	ALENQUER	0,328	54	-0,28	72	18	0,433	71	-0,76	89	18	0,564	89	-1,09	106	17
7	ALMEIRIM	0,395	14	3,55	6	-8	0,526	14	3,37	6	-8	0,642	21	0,85	47	26
8	ALTAMIRA	0,386	19	2,44	15	-4	0,534	10	3,21	7	-3	0,665	13	2,22	18	5
9	ANAJÁS	0,197	128	-2,14	132	4	0,307	140	-2,30	134	-6	0,484	138	-3,91	140	2
10	ANANINDEUA	0,516	2	5,62	2	0	0,606	2	5,03	2	0	0,718	2	3,95	2	0
11	ANAPU	0,025	140	-1,54	118	-22	0,392	103	-1,39	105	2	0,548	105	-0,93	103	-2
12	AUGUSTO CORRÊA	0,238	115	-2,39	139	24	0,335	133	-1,75	119	-14	0,52	123	-0,71	93	-30
13	AURORA DO PARÁ	0,259	101	-0,99	97	-4	0,358	124	-1,73	118	-6	0,519	124	-1,17	110	-14
14	AVEIRO	0,281	88	-0,63	81	-7	0,368	117	-1,76	120	3	0,541	115	-1,98	122	7
15	BAGRE	0,241	113	-2,39	138	25	0,33	136	-2,56	139	3	0,471	141	-3,11	138	-3
16	BAIÃO **	0,336	48	-0,62	80	32	0,459	48	-0,34	78	30	0,578	78	0,01	76	-2
17	BANNACH	0,305	73	0,34	53	-20	0,424	80	-0,61	88	8	0,594	57	0,25	65	8
18	BARCARENA	0,447	4	3,37	8	4	0,554	4	2,91	10	6	0,662	14	2,08	19	5
19	BELÉM	0,562	1	8,20	1	0	0,644	1	6,67	1	0	0,746	1	4,73	1	0
20	BELTERRA	0,311	66	-0,79	89	23	0,396	99	-1,60	113	14	0,588	67	-0,40	86	19
21	BENEVIDES	0,368	29	2,01	19	-10	0,529	13	2,61	14	1	0,665	13	2,88	7	-6
22	BOM JESUS DO TOCANTINS	0,309	69	0,35	52	-17	0,429	77	-0,82	92	15	0,589	65	0,35	59	-6
23	BONITO	0,241	113	-1,92	126	13	0,381	108	-1,59	112	4	0,546	111	0,34	61	-50
24	BRAGANÇA	0,325	58	0,18	57	-1	0,458	49	0,44	55	6	0,6	47	0,14	69	22
25	BRASIL NOVO	0,288	82	-0,87	92	10	0,433	71	-0,54	85	14	0,613	37	0,26	64	27
26	BREJO GRANDE DO ARAGUAIA	0,258	103	-1,61	119	16	0,496	27	0,52	51	24	0,591	60	0,22	68	8
27	BREU BRANCO *	0,293	79	-0,36	75	-4	0,422	84	-0,35	80	-4	0,568	86	0,65	53	-33
28	BREVES	0,284	85	-0,85	91	6	0,372	113	-0,96	96	-17	0,503	133	-2,70	132	-1
29	BUJARU	0,336	48	-0,53	79	31	0,395	101	-1,53	109	8	0,552	100	-0,69	92	-8
30	CACHOEIRA DO PIRIÁ	0,203	127	-0,64	82	-45	0,301	141	-0,42	83	-58	0,546	111	-1,57	117	6
31	CACHOEIRA DO ARARI	0,324	59	-1,95	128	69	0,427	78	-3,23	142	64	0,473	140	-2,76	133	-7
32	CAMETÁ **	0,328	54	-0,15	66	12	0,432	73	-0,24	74	1	0,577	80	-1,06	104	24
33	CANAÃ DOS CARAJÁS	0,276	92	-1,53	117	25	0,456	50	0,62	47	-3	0,673	8	2,85	8	0
34	CAPANEMA	0,425	7	2,93	10	3	0,533	11	2,60	15	4	0,655	17	2,24	17	0
35	CAPITÃO POÇO	0,279	89	-1,01	99	10	0,379	109	-1,06	100	-9	0,548	105	-0,76	96	-9
36	CASTANHAL	0,424	8	3,72	5	-3	0,55	6	3,53	4	-2	0,673	8	2,77	9	1
37	CHAVES	0,179	131	-2,31	135	4	0,289	142	-3,23	141	-1	0,453	142	-4,84	143	1
38	COLARES	0,389	17	1,32	29	12	0,524	15	1,65	25	10	0,602	46	0,70	52	6
39	CONCEIÇÃO DO ARAGUAIA	0,371	26	1,80	22	-4	0,512	21	2,32	17	-4	0,64	23	1,30	33	10
40	CONCÓRDIA DO PARÁ	0,287	83	-0,30	74	-9	0,402	96	-0,89	93	-3	0,566	87	-0,03	77	-10
41	CUMARU DO NORTE	0,309	69	1,13	34	-35	0,405	95	0,21	62	-33	0,55	102	-1,12	107	5
42	CURIONÓPOLIS	0,326	57	0,88	37	-20	0,449	58	0,59	48	-10	0,636	25	1,46	30	5
43	CURRALINHO	0,229	120	-2,15	133	13	0,323	137	-2,25	131	-6	0,502	135	-3,16	139	4

* municipality upstream Tucuruí

** municipality downstream Tucuruí

		1991					2000					2010				
Code	Names	MHDI	rank_MHDI	Comp.1	rank_Comp.1	Δ	MHDI	rank_MHDI	Comp.1	rank_Comp.1	Δ	MHDI	rank_MHDI	Comp,1	rank_Comp,1	Δ
44	CURUÁ	0,194	129	-2,37	137	8	0,383	107	-2,13	129	22	0,578	78	-0,48	87	9
45	CURUÇÁ	0,339	41	0,52	46	5	0,474	36	1,16	34	-2	0,582	74	0,59	56	-18
46	DOM ELISEU	0,299	74	-0,10	63	-11	0,452	55	0,27	58	3	0,615	36	1,10	37	1
47	ELDORADO DOS CARAJÁS	0,026	137	-1,05	100	-37	0,389	106	-1,08	101	-5	0,56	95	-0,15	80	-15
48	FARO	0,281	88	-1,52	116	28	0,431	74	-1,03	98	24	0,563	91	-0,74	95	4
49	FLORESTA DO ARAGUAIA	0,209	124	-2,37	136	12	0,411	91	-1,02	97	6	0,583	72	-0,79	97	25
50	GARRAFÃO DO NORTE	0,183	130	-2,77	141	11	0,331	134	-2,53	138	4	0,526	121	-1,26	114	-7
51	GOIANÉSIA DO PARÁ *	0,235	117	-1,36	110	-7	0,422	84	0,08	65	-19	0,56	95	0,09	74	-21
52	GURUPÁ	0,209	124	-1,93	127	3	0,349	131	-1,71	116	-15	0,509	128	-2,78	134	6
53	IGARAPÉ-AÇU	0,341	40	0,87	38	-2	0,459	48	0,56	50	2	0,595	53	0,34	60	7
54	IGARAPÉ-MIRI **	0,322	61	0,00	60	-1	0,416	88	-0,60	86	-2	0,547	108	-1,57	116	8
55	INHANGAPI	0,327	56	-0,45	77	21	0,438	66	-0,31	77	11	0,572	83	-0,11	78	-5
56	IPIXUNA DO PARÁ	0,268	98	-1,43	111	13	0,317	138	-1,99	127	-11	0,489	137	-2,07	126	-11
57	IRITUIA	0,271	96	-1,30	107	11	0,419	87	-0,37	82	-5	0,559	96	-0,39	85	-11
58	ITAITUBA	0,355	34	1,91	20	-14	0,489	29	1,37	33	4	0,64	23	1,66	24	1
59	ITUPIRANGA *	0,258	103	-1,24	106	3	0,354	126	-2,20	130	4	0,528	120	-1,25	113	-7
60	JACAREACANGA	0,242	111	0,46	50	-61	0,371	115	-0,61	87	-28	0,505	131	-1,77	119	-12
61	JACUNDÁ *	0,367	30	1,79	23	-7	0,477	32	1,76	21	-11	0,622	33	1,07	38	5
62	JURUTI	0,313	64	-1,12	101	37	0,389	106	-2,01	128	22	0,592	58	-0,90	102	44
63	LIMOEIRO DO AJURU **	0,003	143	-1,45	112	-31	0,373	111	-2,27	133	22	0,541	115	-2,83	135	20
64	MÃE DO RIO	0,382	20	1,04	36	16	0,466	43	0,69	45	2	0,599	48	0,71	51	3
65	MAGALHÃES BARATA	0,342	39	-0,29	73	34	0,429	77	1,04	37	-40	0,597	50	1,36	31	-19
66	MARABÁ	0,401	11	2,76	13	2	0,536	8	2,77	13	5	0,668	10	2,31	14	4
67	MARACANÃ	0,313	64	-0,90	94	30	0,406	94	-0,79	90	-4	0,57	84	-0,29	83	-1
68	MARAPANIM	0,337	45	0,45	51	6	0,448	60	0,99	39	-21	0,609	39	1,04	41	2
69	MARITUBA	0,397	13	1,82	21	8	0,505	24	1,66	24	0	0,676	5	3,22	5	0
70	MEDICILÂNDIA	0,293	79	0,13	58	-21	0,47	38	0,58	49	11	0,582	74	-0,12	79	5
71	MELGAÇO	0,177	132	-2,85	142	10	0,26	143	-3,60	143	0	0,418	143	-4,58	142	-1
72	MOCAJUBA **	0,354	35	0,50	47	12	0,443	63	0,20	63	0	0,575	81	-0,82	99	18
73	MOJU	0,289	80	-1,22	104	24	0,399	98	-1,29	103	5	0,547	108	-1,13	108	0
74	MONTE ALEGRE	0,349	36	0,06	59	23	0,467	41	0,04	66	25	0,589	65	-0,48	88	23
75	MUANÁ	0,305	73	0,22	56	-17	0,35	129	-1,46	106	-23	0,547	108	-1,84	120	12
76	NOVA ESPERANÇA DO PIRIÁ	0,229	120	-3,08	143	23	0,315	139	-2,84	140	1	0,502	135	-2,31	129	-6
77	NOVA IPIXUNA *	0,238	115	-1,75	124	9	0,432	73	-0,35	79	6	0,581	76	0,25	66	-10
78	NOVA TIMBOTEUA	0,361	32	0,58	45	13	0,469	40	0,17	64	24	0,609	39	1,15	35	-4
79	NOVO PROGRESSO	0,377	21	1,25	31	10	0,466	43	1,54	29	-14	0,673	8	3,24	4	-4
80	NOVO REPARTIMENTO *	0,222	121	-1,75	123	2	0,372	113	-1,79	121	8	0,537	117	-1,16	109	-8
81	ÓBIDOS	0,347	38	0,24	55	17	0,452	55	-0,11	70	15	0,594	57	-1,18	112	55
82	OEIRAS DO PARÁ	0,268	98	-1,24	105	7	0,36	122	-1,56	111	-11	0,507	129	-2,23	128	-1
83	ORIXIMINÁ	0,039	133	1,28	30	-103	0,517	18	1,61	27	9	0,623	31	-0,57	89	58
84	OURÉM	0,332	51	-0,03	61	10	0,436	67	0,21	61	-6	0,568	86	-0,35	84	-2
85	OURILÂNDIA DO NORTE	0,309	69	-0,24	71	2	0,438	66	0,21	60	-6	0,624	30	1,70	23	-7
86	PACAJÁ	0,257	105	-1,66	122	17	0,34	132	-1,71	117	-15	0,515	126	-2,43	131	5

* municipality upstream Tucuruí
** municipality downstream Tucuruí

		1991					2000					2010				
Code	Names	MHDI	rank_MHDI	Comp.1	rank_Comp.1	Δ	MHDI	rank_MHDI	Comp.1	rank_Comp.1	Δ	MHDI	rank_MHDI	Comp,1	rank_Comp,1	Δ
87	PALESTINA DO PARÁ	0,295	77	-1,49	114	37	0,455	51	-0,18	73	22	0,589	65	0,37	58	-7
88	PARAGOMINAS	0,336	48	1,66	26	-22	0,471	37	1,73	22	-15	0,645	20	1,93	21	1
89	PARAUAPEBAS	0,439	5	4,02	3	-2	0,553	5	3,69	3	-2	0,715	3	3,93	3	0
90	PAU D'ARCO	0,023	141	-0,90	93	-48	0,401	97	-1,18	102	5	0,574	82	-0,22	82	0
91	PEIXE-BOI	0,337	45	-0,12	64	19	0,446	61	-0,35	81	20	0,581	76	0,23	67	-9
92	PIÇARRA	0,208	126	-2,67	140	14	0,37	116	-1,55	110	-6	0,563	91	0,11	71	-20
93	PLACAS	0,276	92	-0,51	78	-14	0,39	104	-1,69	115	11	0,552	100	-1,55	115	15
94	PONTA DE PEDRAS	0,335	49	-0,23	70	21	0,444	62	-0,16	72	10	0,562	93	-1,58	118	25
95	PORTEL	0,272	94	-0,73	86	-8	0,359	123	-0,95	95	-28	0,483	139	-3,04	136	-3
96	PORTO DE MOZ	0,218	122	-1,18	103	-19	0,36	122	-1,05	99	-23	0,503	133	-2,31	130	-3
97	PRAINHA	0,245	110	-2,22	134	24	0,361	120	-2,27	132	12	0,523	122	-3,08	137	15
98	PRIMAVERA	0,248	109	-0,71	85	-24	0,43	75	0,30	57	-18	0,577	80	0,11	72	-8
99	QUATIPURU	0,027	136	-0,78	88	-48	0,406	94	-0,89	94	0	0,543	113	-0,82	100	-13
100	REDENÇÃO	0,374	23	2,41	16	-7	0,53	12	2,99	8	-4	0,672	9	2,89	6	-3
101	RIO MARIA	0,295	77	0,46	49	-28	0,499	26	2,09	20	-6	0,638	24	2,27	16	-8
102	RONDON DO PARÁ	0,392	15	2,01	18	3	0,461	46	1,09	36	-10	0,602	46	0,77	50	4
103	RURÓPOLIS	0,257	105	-2,14	130	25	0,421	85	-1,48	107	22	0,548	105	-1,88	121	16
104	SALINÓPOLIS	0,399	12	2,88	12	0	0,517	18	2,99	9	-9	0,647	18	2,32	13	-5
105	SALVATERRA	0,391	16	1,10	35	19	0,478	31	0,82	43	12	0,608	41	1,33	32	-9
106	SANTA BÁRBARA DO PARÁ	0,369	27	1,54	27	0	0,505	24	1,55	28	4	0,627	29	1,75	22	-7
107	SANTA CRUZ DO ARARI	0,003	143	0,27	54	-89	0,393	102	0,27	59	-43	0,557	98	0,46	57	-41
108	SANTA ISABEL DO PARÁ	0,447	4	2,96	9	5	0,535	9	2,82	12	3	0,659	16	2,48	12	-4
109	SANTA LUZIA DO PARÁ	0,274	93	-1,65	121	28	0,362	118	-1,84	123	5	0,546	111	-0,65	91	-20
110	SANTA MARIA DAS BARREIRAS	0,327	56	0,49	48	-8	0,408	92	-0,79	91	-1	0,544	112	-0,73	94	-18
111	SANTA MARIA DO PARÁ	0,368	29	1,77	24	-5	0,463	45	0,72	44	-1	0,598	49	1,04	40	-9
112	SANTANA DO ARAGUAIA	0,331	52	1,15	33	-19	0,45	57	0,30	56	-1	0,602	46	0,95	44	-2
113	SANTARÉM	0,337	45	2,91	11	-34	0,424	80	2,90	11	-69	0,691	4	2,06	20	16
114	SANTARÉM NOVO	0,421	10	0,63	44	34	0,555	3	-0,30	75	72	0,587	68	0,62	55	-13
115	SANTO ANTÔNIO DO TAUÁ	0,365	31	0,80	40	9	0,475	34	1,16	35	1	0,632	27	1,59	25	-2
116	SÃO CAETANO DE ODIVELAS	0,337	45	-0,17	67	22	0,464	44	0,51	52	8	0,585	70	1,10	36	-34
117	SÃO DOMINGOS DO ARAGUAIA	0,285	84	-0,76	87	3	0,454	52	-0,30	76	24	0,594	57	0,27	63	6
118	SÃO DOMINGOS DO CAPIM	0,033	135	-0,17	68	-67	0,371	115	-1,48	108	-7	0,532	118	-1,98	123	5
119	SÃO FÉLIX DO XINGU	0,315	62	-0,22	69	7	0,435	68	0,47	53	-15	0,594	57	0,29	62	5
120	SÃO FRANCISCO DO PARÁ	0,371	26	1,16	32	6	0,476	33	1,38	32	-1	0,608	41	1,56	27	-14
121	SÃO GERALDO DO ARAGUAIA	0,256	106	-1,63	120	14	0,415	90	-0,09	68	-22	0,595	53	1,02	42	-11
122	SÃO JOÃO DA PONTA	0,282	86	-0,99	98	12	0,448	60	0,45	54	-6	0,583	72	0,82	48	-24
123	SÃO JOÃO DE PIRABAS	0,306	70	-0,41	76	6	0,415	90	-0,11	69	-21	0,539	116	-0,58	90	-26
124	SÃO JOÃO DO ARAGUAIA	0,233	118	-1,32	109	-9	0,349	131	-2,32	135	4	0,55	102	-0,84	101	-1
125	SÃO MIGUEL DO GUAMÁ	0,322	61	-0,13	65	4	0,453	53	-0,05	67	14	0,591	60	0,14	70	10
126	SÃO SEBASTIÃO DA BOA VISTA	0,288	82	-1,46	113	31	0,422	84	-1,30	104	20	0,558	97	-2,04	125	28
127	SAPUCAIA	0,311	66	0,86	39	-27	0,469	40	1,66	23	-17	0,59	61	1,51	29	-32
128	SENADOR JOSÉ PORFÍRIO	0,253	108	-0,83	90	-18	0,361	120	-1,69	114	-6	0,514	127	-2,04	124	-3
129	SOURE	0,427	6	3,53	7	1	0,513	19	1,63	26	7	0,615	36	1,06	39	3

* municipality upstream Tucuruí

** municipality downstream Tucuruí

		1991					2000					2010				
Code	Names	MHDI	rank_MHDI	Comp.1	rank_Comp.1	Δ	MHDI	rank_MHDI	Comp.1	rank_Comp.1	Δ	MHDI	rank_MHDI	Comp,1	rank_Comp,1	Δ
130	TAILÂNDIA	0,034	134	0,77	41	-93	0,433	71	0,89	40	-31	0,588	67	1,19	34	-33
131	TERRA ALTA	0,266	99	-0,69	83	-16	0,474	36	0,88	41	5	0,605	42	0,88	46	4
132	TERRA SANTA	0,334	50	-0,70	84	34	0,49	28	0,63	46	18	0,635	26	0,80	49	23
133	TOMÉ-AÇU	0,347	38	0,65	43	5	0,438	66	0,83	42	-24	0,586	69	0,64	54	-15
134	TRACUATEUA	0,025	140	-1,90	125	-15	0,357	125	-2,48	137	12	0,531	119	-1,08	105	-14
135	TRAIRÃO	0,271	96	-0,95	95	-1	0,395	101	-1,88	124	23	0,562	93	-0,80	98	5
136	TUCUMÃ	0,305	73	-0,07	62	-11	0,512	21	2,20	18	-3	0,659	16	2,66	11	-5
137	TUCURUÍ	0,421	10	3,80	4	-6	0,543	7	3,47	5	-2	0,666	11	2,68	10	-1
138	ULIANÓPOLIS	0,277	90	1,37	28	-62	0,42	86	1,03	38	-48	0,604	43	0,11	73	30
139	URUARÁ	0,298	75	-0,96	96	21	0,45	57	-0,12	71	14	0,589	65	-0,17	81	16
140	VIGIA	0,372	24	2,37	17	-7	0,487	30	2,17	19	-11	0,617	34	1,58	26	-8
141	VISEU	0,237	116	-2,11	129	13	0,353	127	-1,90	125	-2	0,515	126	-1,17	111	-15
142	VITÓRIA DO XINGU	0,262	100	-1,49	115	15	0,422	84	-0,46	84	0	0,596	51	0,05	75	24
143	XINGUARA	0,374	23	2,66	14	-9	0,519	16	2,51	16	0	0,646	19	2,28	15	-4

* municipality upstream Tucuruí

** municipality downstream Tucuruí

Conclusions

The principal components analysis performed on a dataset observed on the 143 municipalities of Pará shows that there is a pattern between the data, which indicate that more than 50% of the variability is explained not only by the components that make up the MHDI but also by access to water and energy. This result confirms the relationship between access and human development explained in the literature. By studying the composition of the main components, we come to the conclusion that Comp.1 can be used as an alternative indicator to MHDI to measure municipal human development. The check of this hypothesis is possible by comparing the rankings of the 143 municipalities assigned respectively on the basis of the MHDI and the so-called MHDI adjusted for accesses (i.e. Comp.1). Although the rankings are very similar, as suggested by Spearman's correlation index, the comparison between the rankings allows identifying which municipalities improve or worsen their position when, in addition to the classic variables, access is considered.

The observation of the results of the two consecutive steps of the analysis is made on a sample of 12 municipalities part of the micro-region of Tucuruí, a pivotal area in the economic, social and environmental debate on the dynamics of sustainable development of Pará. In fact, the area reproduces on a small scale the ambiguous and contradictory dynamics that the Amazon itself lives towards the country, and that Brazil has lived in turn towards the global market since the phase of colonial occupation. The micro-region of Tucuruí is located within one of the largest catchment areas in the world and for this reason, it has an enormous availability of water and therefore a large hydroelectric potential. This potential has attracted large national and international investments that led to the construction of the hydroelectric power plant in Tucuruí in the eighties. To date, the hydroelectric production of Tucuruí meets the more than 5% of the national electricity needs. Nevertheless, access to water as a primary source and to hydropower are at the lowest levels in the country (UNDP, FJP, IPEA, 2013).

According to Goldemberg (1998), the use of energy is a fundamental vehicle for human development. Without taking this into account in our socioeconomic analysis we would omit important information that could worsen (and in fact, we have shown that it worse) the measurement of the level of development, especially in critical areas. Adjusting this information would instead lead to a new dual direction of the actions of policy-makers. On the one hand, an adjusted index of the type we have proposed would induce a better identification of drivers of development, helping in the selection of targeted interventions for its enhancement. In fact, according to Pachauri and Spreng (2003), lack of access to energy is a form of poverty complementary to the income poverty, which in turn is a measure of deprivation of well-being that can also generate social exclusion. At various levels of need, therefore, access to energy is a guarantee of improved well-being, especially in rural areas. On the other hand, the extended approach to access should induce policymakers to critically evaluate the role of large projects for the expansion of installed electrical power with respect to the objectives of regional, local and rural electrification. With this in mind, we hope for a Brazilian political planning aimed at not repeating the mistakes of the past in which the expansion of the national electricity park not only couldn't enhance in any way the local access to the service but also had a negative hidden impact.

According to Scudder (1981), the main negative impact of a large hydroelectric project is the construction of the dam. The social and economic damage caused by the diversion of the river in the case of Tucuruí is described in a broad of literature by P.M. Fearnside (2002, 2001, 1999), while Rocha (2008) says that the formation of the reservoir of Tucuruí caused the flooding of a geographical area on which depended between 6,000 and 10,000 families, the equivalent of 14 communities that lived on the edge of the river basing their economic activity on fishing, as well as on the extraction of minerals and chestnuts. Among the flooded municipalities were Jacundà and Breu Branco, as well as Ipixuna and Repartimento Central, which will later become Nova Ipixuna and Novo Repartimento. Rocha (2015) also highlights that there are some positive impacts. By taking the Tucuruí hydroelectric power plant as a reference, he highlights first and foremost the attraction of the workforce from the surrounding cities and regions. Immigration linked to the construction of the hydroelectric has made the micro-region of Tucuruí the biggest integration region of Pará. The influx of labour force and the consequent increase of the population has given a strong impulse to the construction of infrastructures and to the improvement of services, especially at the urban level. It is no coincidence that Coelho and Goldemberg (2003) point out that access to electricity in urban areas is 99% in all regions of Brazil, but what is worrying is the rural areas, where the percentage is not so high. In fact, the region of the North is, together with the region of the North East, the region with the highest concentration of population living in rural areas, making the issue of access a pivotal matter.

It can then be concluded that not only access but rural access may be the real driver of development. It is essential to note that the intervention in supporting access and thus rural development, especially when it comes to remote and not highly concentrated villages, must have a philanthropic basis, as defined by Coelho and Goldemberg (2003). This is why the importance of the role of the federal government is recalled, which, in our opinion, cannot leave the development objective of the country in the hands of the privatization of both energy production and energy supply. This is stated also in light of the need for federal incentives to self-production from renewable energy, a fundamental resource for rural electrification in the unfeasibility to create links to the SIN[60] (because too expensive or unfeasible). Without taking into account the important role of specific programs for the development of rural areas, such as *Luz para Todos* and *Água para todos*, which have guaranteed access to energy by making up for the impossibility of connecting to the national transmission system and operating where large projects of sectoral interest have been lacking.

In conclusion, it can be said that producing a lot of energy can be an impulse for economic growth, but not certainly for development. What boost the human development of a country is the access to energy, conveyed by infrastructure (extension of the national transmission system) and the reduction of costs for final consumers, both in rural areas and in marginal urban areas. Thus, as hunger and famine are not always the result of the scarcity of resources but sometimes simply result from misallocation, in the same way, the abundant energy production in Brazil will have to deal with the lack of energy not due to scarcity but due to affordability. At that point, a change would be expected, mainly with regard to policy indications which, rather than being oriented towards industrial policies (such as tax breaks for the production of energy/consumption of electricity by large companies), should be more oriented to rural electrification. It may be achieved by enhancing infrastructures, auto production and the reduction of the cost of energy - the three main factors of inadequate

60 The SIN is the Brazilian electricity generation and transmission system. It consists of a set of facilities and equipment that enable the supply of electricity in the regions of the country that are electrically interconnected, according to applicable regulations. It has four subsystems: South, Southeast / Center-West, Northeast and most of the North (ONS, available at: http://ons.org.br/paginas/sobre-o-sin/o-que-e-o-sin).

access - paying particular attention in the case of the Amazon to safeguarding the role of water not only as a primary source of energy production, but as a basic element of human life.

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Ph.D. in Economics
CYCLE XXXI

Third Paper

A spatial panel analysis of the Municipal Human Development Index among the municipalities of the State of Pará in the Brazilian Amazon

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References

Abstract

By performing a Principal Component Analysis in the second paper we showed how the measurement of development at the municipal level in the State of Pará in the North Region of Brasil is clearly affected by the observation of the variables of access. In the light of this evidence, the aim of this paper is to measure the role of access – both to water and to energy - in shaping the Municipal Human Development Index (MHDI) as supplied by UN, IPEA and FJP (2013). A fixed effect model for spatial panel data is applied on socio-economic data regarding 143 municipalities belonging to the state of Pará, which were made available for the years of the last three census (1991, 2000 and 2010) by IBGE, IPEA and FJP (2013). The results show positive and significant coefficients for both of the variables of access (i.e. water and electricity) and in both of the specifications presented, nevertheless carrying positive and significant coefficients of inequality. Furthermore, the model tried to evaluate whether and to what extent the MHDI indicates any kind of spatial correlation among the error terms, finally showing a positive and significant one for both of the specifications. Eventually, the presence of significant fixed effects just for some of the municipalities lead to a more in-depth qualitative analysis of their historical and economic background.

JEL Codes: O15, O44, O54

Keywords: Municipal HDI, Pará, spatial panel, energy justice, access to water, inequality

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Introduction

This chapter is a natural prosecution of chapter two in which a Principal Component Analysis was carried out for the 143 municipalities of the State of Pará in the three years of the 1991, 2000 and 2010 census (IBGE, PNUD, IPEA, FJP). This analysis has highlighted that the variables of access to electricity and access to piped water and sanitary facilities in permanent private homes are influential in determining an alternative measure of human development for the analyzed sample. In the light of the above, considering indicators of access to both water and energy for attempting to evaluate the relative human development objectives achieved by the municipalities under study does not bring major differences in the ranking of the sample compared to the ranking provided by the Municipal Human Development Index – MHDI (UNDP/FJP/IPEA, 2013). However, taking into account the accesses allows observing which units worsen their relative position, betraying the existence of access problems, even in the presence of high incomes. These municipalities are those which, despite the enormous availability of water resources and the increase in incomes, are unable to follow the path of development at the same speed as those which, even in the absence of or in the presence of a smaller endowment of natural resources, approach economic and energy development in a more efficient manner, not having to deal with the resource curse hypothesis nor with the endowment trap. Considering the arguments above, one of the objectives of this chapter is to estimate, through an econometric model, the correlation between access and human development by using as a dependent variable the HDI by UN, acknowledged in the literature as the standard indicator, in its adaptation as a municipal indicator, which is the MHDI. Analyses of the unilateral or bilateral causal relationship between different sources of energy production/consumption (including hydroelectricity) and economic growth are performed in Apergis and Payne (2012), Pao and Fu (2013), Ohler and Fetters (2014), Solarin and Ozturk (2015), Magnani and Vaona (2016), Bildirici (2016) Apergis et al (2016). On the other hand, works estimating the impact of energy access on socioeconomic variables other than simple GDP or per capita income, are very few and they are frequently based on specific case studies such as Sub-Saharan Africa (Nanka-Bruce, 2010; Onyeji et al., 2012) or Brazilian Amazon (Van Els et al., 2012).

In line with what stated by Magnani and Vaona (2016), a fundamental means of development is the capillary electrification of territories that leaves no room for rural marginalization. This issue becomes central in the Brazilian Amazon, of which the state of Pará is a part, which is rich in resources located in endless and not yet densely urbanized territories. Thus, for the sake of human development measurement and according to the case studies abovementioned, our model includes socio-economic monitoring variables such as indicators of housing conditions, educational level and the index of inequality. Moreover, through the use of a spatial matrix, it tries to additionally shape the structure of the spatial correlations between the units in order to capture the geographical information contained within the data panel. The availability of data, especially for the more remote municipalities of Pará, as far as for the whole North and North-East regions of Brazil, has not made it easy to develop case studies on access to energy or even access to water, even less in the case of municipalities. However, with the data made available from 2013 by the Atlas of Human Development of Brazil (UNDP, IPEA, FJP) some authors are beginning to develop socio-economic research on case studies at both regional and local levels, also giving space to the econometric spatial approach (Ferraz, 2016).

The chapter is divided into four sections. The first section take a quick look at spatial econometrics. Thus, section two is dedicated to the literature review. In section three the database is illustrated and the methodological aspects discussed. Section four is devoted to the analysis and discussion of the results. Then, concluding observations and ideas for future reflections are given.

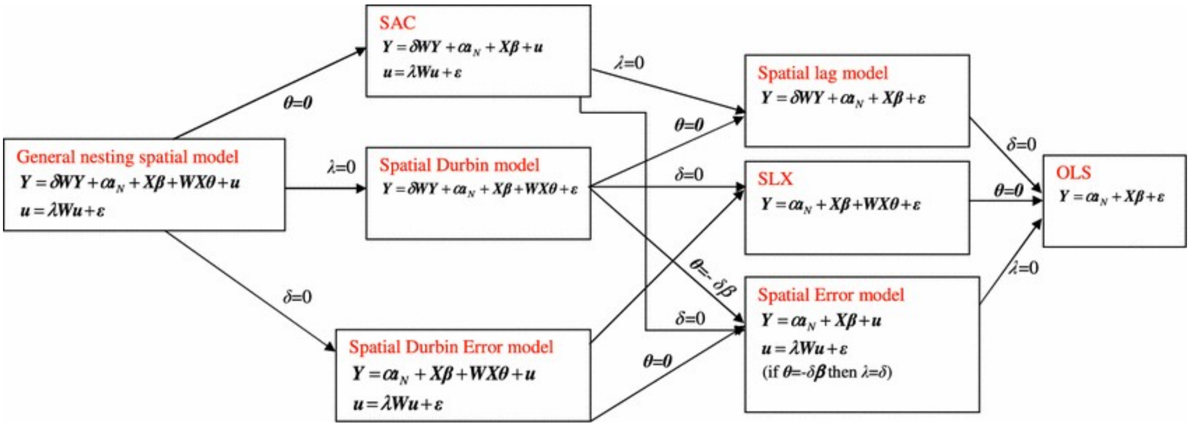
1. Spatial Models

Starting from the idea that in a standard model of linear regression the observed units may interact in space, space econometrics deals with the elaboration of techniques to control these interactions. Provided there may be a spatial dependency, not including a variable that captures this effect could lead to inconsistent or inefficient estimates. So, the goal of space economics is to model this interaction, i.e. to identify the type of spatial interaction that exists in the data and thus which model is the most appropriate to read it (Elhorst, 2010).

The main types of spatial interaction encountered in the literature are endogenous interaction effects among the dependent variables (Y), exogenous interaction effects between the dependent of one unit and the regressor of one another (X) and the interaction effects among the error terms (ε), which are respectively associated with the application of SAR (Spatial Auto-Regressive model), SLX (Spatial Lag of X) and SEM (Spatial Error Model) or self-regressive error model. However, the literature on spatial econometrics is mainily focused on endogenous interactions and interactions among the error terms (Elhorst, 2014). In the case of endogenous interaction (Y), it is verified that the dependent variable of unit i is spatially correlated with the value of the dependent variable of the unit j. That is, the value of the dependent variable is determined jointly with that of the neighbouring agents and this effect is captured by the self-regressive spatial coefficient δ (Elhorst, 2014). One finds oneself instead in the case of interaction between error terms (ε) when the omitted determinants of the dependent variable are spatially correlated, or when an external shock follows a spatial pattern. In this case, the effect is captured by the coefficient of spatial autocorrelation λ (Elhorst, 2014). Starting from the work of Kelejian and Prucha (1998), other authors developed models that control for both of these effects. These models are defined in an equivalent way as SAC (LeSage and Pace, 2009), Kelejian-Prucha model (Elhorst, 2010), SARAR or Cliff-Orf type spatial model (Kaleijan and Prucha, 1998).

Elhorst (2014) presents a review of all possible types of spatial interaction and the models referred to them, also including the effect of exogenous interaction, in which the dependent variable of an individual depends on the explanatory variable of other units. In fact, starting from the spatial extension of the General Nesting Model which includes all types of spatial interaction, the other spatial econometric models can be obtained by imposing restrictions on one or more of the parameters contained in the GNM, where $\lambda=0$ eliminates the effect of spatial interaction between the error terms of different Wu units, $\theta=0$ eliminates the exogenous effect of WX interaction and $\delta=0$ eliminates the endogenous effect of interaction between the WY dependent variables (Figure 1).

Figure 1. Taxonomy of spatial models



Source: Elhorst, 2014

From the taxonomy proposed by Elhorst (2014) it can be deduced that the fulcrum of the spatial econometrics is the matrix W_n that is a non-stochastic matrix that describes the spatial dependence between each couple of cross-sectional unit y_{ij}. It describes the spatial configuration of the sample and must be specified *ex ante*[61]. This matrix is a matrix of known constants, symmetrical and not negative, and has all the diagonal elements equal to zero since no unit can be considered as self-neighbour. It can have different structures: the matrix of contiguity of order p; the inverse matrix of distances; the matrix of the nearest neighbour of order q; the diagonal matrix in blocks. In the case of the matrix of contiguity of order p, which is the case that we are dealing with in the present work, the conditions that limit the correlation of type cross-section to a manageable degree (condition of stationarity) are both met (Elhorst, 2014). This means that, with p small enough and q limited (with q representing the maximum number of possible neighbours for each unit), the spatial correlation between the units converges to zero when the distance separating the units tends to infinity. Estimates of coefficients of spatial models can be made through maximum likelihood estimators (ML), or near-maximum likelihood estimators (QML), instrumental variables (IV) or generalized moment method (GMM). The most common method is the ML method, and it is the one chosen for the present empirical application.

61 However, there are some authors such as Aldstadt and Getis (2006; 2010) who have proposed a method for estimating it.

2. Theoretical backgroung

In 1973 Andrew Cliff, geographer, and Keith Ord, economist, paved the way for the study of spatial autocorrelation in OLS linear regression models, which assume that error terms are independent under the null hypothesis. However, the authors note that in cases where data is sorted geographically even errors may present a specific spatial pattern. Since in practical cases the errors are not observable, Cliff and Ord (1973) propose a statistical test on the correlation of the residual components of the regression estimated without taking into account the spatial pattern.

Anselin (1988), confirms the existence of measurement problems during data collection, specifically when it comes to spatial units e.g. municipalities, states or Minimum Comparable Areas, which are then the most recurrent type of unit in socio-economic studies. The varied and heterogeneous sources of misspecification lead to the violation of the basic assumptions of regression models, so the author, on the one hand, tests the possible sources of misspecification in general, and on the other hand tests the presence of spatial dependence as the primary source of misspecification of the model, even in the presence of other sources of misspecification.

Durbin (1988) criticizes the econometric approach of economists who, when they do not assume a priori the absence of spatial correlation, admit its presence but leave the study to future works or to others. Durbin (1988) proposes a procedure for estimating a regression in the presence of spatially related autocorrelated error terms based on the concept that the correlation between error terms is a function of the distance between units. This function of distance behaves like time in historical series, i.e. error terms should become independent when the distance between observations becomes large enough.

Since the nineties, problems of this kind have become familiar and have given rise to a more extensive literature on specifications, estimates and tests in the field of spatial models as in LeSage (1999a, 1999b), Baltagi et al. (2003), Elhorst (2003, 2010, 2014), Pfaffermayr (2009), Lee and Yu (2010a,2010b), LeSage and Pace (2009,2014), Wang and Lee (2013), also accompanied by a growing interest in specifying and estimating models for panel data from the 2000s. Worthy of note, for example, is the contribution of Kapoor et al. (2007) in relation to the model with spatial correlation of error, which as an alternative to the classic error structure proposed by Baltagi et al. (2003) introduces a model in which not only error terms but also individual components are spatially correlated, sharing the same spatial parameters with the former. The two approaches are therefore different for the matrix of variance that is more complex in Baltagi et al. (2003).

Recent Brazilian socio-economic studies using data related to spatial units such as municipalities or MCA (Minimum Comparable Areas) are progressively embracing the spatial approach to econometric analysis (Lins et al., 2015, Reis et al., 2014, Barufi et al., 2012, Magalhães et al., 2005). In fact, controlling for spatial correlation often mitigate the problem of model misspecification.

Magalhães et al. (2005) try to demonstrate if there is a convergence of per capita incomes among the 26 States of the Brazilian Federation in the period 1970-1995. The study of convergence (absolute and conditional) induces the author to reflect on the fact that many studies already carried out on the subject did not test for the presence of spatial correlation, from which it deduces that the estimates thus calculated can be distorted. In fact, the indication of a possible spatial correlation is already evident from the descriptive statistics on regional per capita income, well below the country average in the North and North-East regions, even above the country average in the South and South East ones, throughout the reference period. The Moran index applied to the data confirms both the presence of spatial correlation and the division into income clusters. The separation of units obtained from the Moran plot follows the pattern in which states with high per capita income are surrounded by states with high per capita income (high to high type) and states with low per capita income are surrounded by states with low per capita income (low to low type). The described pattern remains about stable between 1970 and 1995, as do stable outliers, suggesting the hypothesis of club convergence instead of an absolute one. Starting from the intuitions arising from the descriptive and exploratory analysis of the data, Magalhães et al. (2005) apply an OLS model of convergence, whose residues are tested for the presence of spatial correlation. The spatial correlation of the model's residues denounces a bad specification of the model, that the authors decide to correct through the application of a spatial model controlling for the correlation between error terms. Magalhães et al. (2005) propose three types of models each checking for a different spatial correlation (endogenous, exogenous or error correlation), the best of which (selected according to the AIC and SC criteria) is the one checking for space lags. The authors first deduce that studying convergence without taking into account the spatial correlation of the units risks causing distorted estimates due to the poor specification of the model. In the Brazilian case, by the application of a spatial approach, the results confirm that even in the presence of a weak convergence at federation level, convergence clubs can be identified, geographically located to create space clusters about corresponding to the two biggest areas North-North-East and South-South-West, duly taken into account the outliers (e.g. the Federal District).

The results in terms of absolute convergence and convergence by clusters were also achieved by Reis (2014). The author, combining statistical analysis and thematic mapping for 432 Minimum Comparable Areas between 1872 and 2000, uses a spatial approach, starting from the observation of spatial patterns of growth that emerged from the maps, to analyze the issue of inequality in Brazil. The author highlights the economic drivers of both development (e.g. rubber boom or import substitution industrialization) and convergence (e.g. geographic factors such as transport costs), with the aim of expounding the temporal trend and spatial distribution of per capita income and labour productivity in the MCAs - chosen in place of the municipalities which in turn are subject to territorial and administrative changes in the reference period. A slow convergence within the five large regions and a faster divergence between different regions results from the OLS estimates of β-convergence, which outline the presence of at least 5 clusters, each corresponding to a macro-region, proving the presence of regional disparity. Moreover, the convergence of labour productivity in urban and rural areas reproduces an alternatively high-high or low-low type of behaviour. Starting from the latest results, an in-depth analysis using SACD (endogenous spatial correlation), SACR (errors autocorrelation) and SURE+SAC (both of the above-mentioned correlations) models are applied to verify the presence of synergies between urban and rural sectors. The SACR and SURE+SAC estimates are similar and significantly different from the OLS estimates, so it can be deduced that the spatial correlation to be controlled by the model is the one between the error terms that, according to Reis et al. (2014) induce the "spatial contagion". Moreover, even though there are separate patterns between the urban (fastest) and rural sectors in terms of labour productivity, the two sectors are clearly linked by spatial inertia, the main determinants of which are the distance from the capital and the presence of transport infrastructures.

Also Lins et al. (2015) use models for the joint control of endogenous spatial correlation, on smaller administrative units than the MCA (i.e. municipalities) and on a reduced time frame. In a non-spatial model for the determination of the evolution of the MHDI between 2000 and 2010 of 1793 municipalities of the North-East region, Lins et al. (2015) identify the possible presence of spatial clusters starting from the descriptive analysis of the dependent variable. This presence of space clusters, suggested by the concentration of municipalities with higher or lower MHDI in different states of the macro region, is tested in two phases. At first, the Global Moran Index provides evidence of the absence of spatial randomness of errors, while at a second time the local Moran Index identifies clusters of MHDI (high-high and low-low) and outliers (high-low, low-high). Starting from the exploratory analysis on the non-spatial model the hypothesis of absence of spatial autocorrelation of residues is tested, which is therefore rejected. Given the results of the residue test, Lins al. (2015) look for possible alternative models to check for spatial correlation of data. These models are the SAR (spatial autoregressive model), the SEM (spatial error model) and the SAC (mixed model, including both endogenous spatial correlation and spatial error correlation). The models are compared through relative indexes of fitting, as well as through the application of the autocorrelation test of residues, as was done for the non-spatial model. The most suitable model is the SAC model, which corresponds to the highest levels of AIC and BIC, the lowest LIK, and the absence of autocorrelation of the error. The SAC model confirms the existence of a β convergence of the municipalities of the North-East region in terms of MHDI, however it indicates how the variables of access to water (percentage of population living in private homes with piped water and sanitation) and access to energy (percentage of population living in private homes with lighting and electricity services) explain a part of the growth rate between 2000 and 2010.

Also, the analysis of other socioeconomic variables can present geographical patterns useful to describe not only the dynamics of economic growth but also the more complex ones of development, which economic growth directly or indirectly boost. Barufi et al. (2012), starting from the mapping of the infant mortality index in the MCAs of Brazil, identifies at least two performance clusters, the one with the highest infant mortality rate corresponding to the area of the North East region and the one with the lowest infant mortality rate corresponding to the South region. According to Barufi et al. (2012), the income variable plays a direct role in increasing development, but also has an indirect role that passes through the strengthening of health conditions due to both the improvement of welfare (public intervention) and the standard of living. However, according to the authors, it is necessary to check for other variables such as the presence and cost of public services, the presence and quality of health infrastructure, vulnerability to poverty, inequality and the level of urbanization (excluding, on the basis of the previous literature, the fertility rate of children). In this sense, the authors use a panel model on 10,977 MCAs in the time frame between 1980 and 2000 to capture individual effects, but consider a spatial panel model to capture spatial correlation. The sample, which is exhaustive, requires the use of a fixed structure of individual effects for the application of both models each capturing a different type of spatial correlation (endogenous or error). From the fitting measures proposed by the author, the models are all better than the pooled model, a sign that by not capturing the spatial effect, distorted estimates are obtained. However, since there is no substantial difference between the two models considered, it can be concluded that unlike the SAR model, the SEM model does not have counterintuitive results, but underlines the predominant role of access to water and sanitation, as well as infrastructure as the main vehicle for spillovers.

3. Method

3.1. Spatial econometric for panel data

According to Elhorst (2014), the growing interest in the application of spatial econometrics to panel-type data in socioeconomic studies is justified by the fact that panel-type data offer researchers a wide range of modelling possibilities compared to the mono equation setting of cross-section data, to which the first part of the available spatial literature refers. If the panel structure already allows to increase and improve information and reduce collinearity by augmenting the degrees of freedom to obtain more precise estimates of a multiple linear regression (Andreß et al., 2013), modelling the spatial interaction of the data would also mean controlling part of the unobserved heterogeneity (Lee and Yu, 2010a). The dominant literature establishes that models for extended panel data including the spatial panel data model have the following characteristics:

can control for endogenous interaction effects;

can control for effects of spatial interaction between error terms;

can control for exogenous interaction effects;

can include more than one type of interaction;

the matrix of weights W is constant over time;

the panel must be balanced,

although there are isolated works by authors who have not renounced exploring cases in which the W matrix varies over time (dynamic models) (Lee and Yu,2010b) or cases in which the panel is unbalanced (Pfaffermayr, 2009). Therefore, taking into account heterogeneity means taking into account both spatial specific error that is time-invariant (e.g. the location of a municipality at sea level or in the mountains) and temporal specific error that is space invariant (e.g. en economic recession). As in the classical panel data models, the modelling allows for two different structures of the specific effects, that is fixed effects (FE) or random effects (RE). In literature, RE is much more used than FE (Elhorst, 2014). In fact, first of all, the RE model is well suited to samples with a large N and representative of a larger population. Secondly, estimates of specific effects in the case of FE are consistent only when T is large enough, since the number of observations useful for estimating each individual effect μ_i is T, thus leading to an incidental parameter problem[62]. However, since in most socio-economic studies the focus is on the regressors' coefficients β and not on μ, it is important to note that inconsistent estimates of individual effects do not affect β estimates.

In the empirical application here presented, the population analyzed represents itself, that is, the sample is exhaustive and consists of 143 units representing all the municipalities of the state of Pará observed at the three last censuses 1991, 2000 and 2010. Since the number of the units within the sample has an upper limit and the number of temporal observations is T=3, the research limits itself to making conditional inference on the specific exhaustive sample, of

62 If T is fixed, as N is large the structural parameters estimates become biased. This occurs because the number of nuisance parameters grow quickly as N increases.

which the individual effects are then determined. Such kind of model is obviously modelled as fixed, without specifying the type of structure *à la* Kapoor or *à la* Baltagi[63].

3.2. Dataset

In this work we investigate whether and to what extent access to energy and access to water play a role in influencing the level of human development in the state of Pará[64], controlling for a number of socioeconomic variables. The units observed are N=143 municipalities, and the dependent variable is the Municipal Human Development Index (MHDI) proposed by the Atlas de desenvolvimento humano do Brasil (UNDP, IPEA, FJP, 2013). The MHDI is derived from a calculation method similar to that used to calculate the Human Development Index (HDI) at the country level, i.e. it is a geometric mean that takes into account three dimensions such as long and healthy life, decent standard of living and knowledge. While the first dimension is expressed by life expectancy at birth both at country and local level, it should be borne in mind that HDI and MHDI cannot be compared since the indicators chosen for the other two dimensions are not the same. In fact, on the one hand, the local standard of living is expressed by per capita income instead of the gross national product as is the case for HDI. On the other hand, the knowledge indicator is, in turn, a geometric average of two knowledge indices which are, however, different from those contained in the HDI. In fact, in the HDI the knowledge indicator is constructed as a geometric mean of the expectation of years of study (future projection) and the average of years of study of the population aged over 25 (photograph of the past). On the other hand, in MHDI the geometric mean is carried out between the schooling index of the adult population, i.e. the percentage of adults who have completed education (past photograph) which has a weight of 1, and the flow of the school-age population into the school system (present photograph) which has a weight of 2[65].

63 In the FE models the two specifications are equivalent from the empirical point of view, since the "within" transformation eliminates the individual effects.

64 Mojuì dos Campos (for which there are no censorship data since it detached from Santarém in 2012) and Monsaràs (considered a district of Salvaterra since 2005) are not included. Vila Franca is also kept out because it has not been on the list of municipalities since 1991 (Source: IBGE).

65 At the municipal level, greater attention is given to current performance than future projections.

Figure 2. Explanatory variables for analysing the MHDI

Variables		Definitions
Municipal Human Development Index	MHDI (dependent)	Municipal Human Development Index. Geometric mean of the indices of the Income, Education and Longevity dimensions, with equal weights.
Percentage of the population living in households with bathrooms and running water	T_BANAGUA	Ratio of the population living in permanent private households with water channeled to one or more rooms and with private bathroom and the total population living in permanent private households multiplied by 100. Water may be provided by the general network, from the well, directly from the source or from reservoirs supplied by rainwater or by tank trucks for water.
Percentage of the population living in households with running water	T_AGUA	Ratio of the population living in permanent private households with water channelled to one or more rooms and the total population living in permanent private households multiplied by 100. Water may be provided by the general network, from a well, directly from the source or from reservoirs supplied by rainwater or by tank trucks for water.
Percentage of the population living in households with a density of more than 2 persons per dormitory	T_DENS	Ratio between the population living in permanent private households with a density greater than 2 and the total population living in permanent private households multiplied by 100. The density of the household is given by the ratio of the total number of dwellers in the household to the total number of rooms used as a dormitory.
Percentage of the population living in households with electricity	T_LUZ	Ratio between the population living in permanent private households with electric lighting and the total population living in permanent private households multiplied by 100. One takes into account the illumination coming or not from a general network, with or without energy meter (gauge that measures energy used).
Expectation of years of study at age of 18	E_ANOSESTUDO	Average number of years of study that a generation of children entering school must complete at age 18 if current standards are maintained throughout their school life.
Illiteracy rate of the population aged 11 years and over	T_ANALF	Ratio between people aged 11 years or over who can not read or write a straightforward ticket and the total number of people in this age group multiplied by 100. It is the mean (weighted for population) of the illiteracy rates in the four main age categories (11-14;15-17;18-24;over 25).
Gini Index	GINI	Measures the degree of inequality in the distribution of individuals by household income per capita. Its value varies from 0, when there is no inequality (household income per capita of all individuals has the same value), a 1, when the inequality is maximum (only one individual owns all income). The universe of individuals is limited to those living in permanent private households.

Source: Personal elaboration from UNDP, FJP, IPEA 2013

We use as explanatory variables the following access variables: percentage of the population living in permanent private households with piped water (T_AGUA), percentage of the population living in permanent private households with piped water and sanitation (T_BANAGUA) and percentage of the population living in permanent private households with electricity (T_LUZ), checking for an additional housing condition indicator that is the population density per dormitories in private and permanent households (T_DENS). It should

be noted that the two water access indicators are alternative and therefore used separately in two different model specifications. Other explanatory variables will be those of education, not redundant with those contained in the calculation of MHDI: the expectation of years of study at 18 years for children entering the school system (E_ANOSESTUDO) and the illiteracy rate of the population over 11 years (T_ANALF). Finally, the GINI index is considered as a measure of inequality in the light of the unsatisfactory results at the national level (Figure 2).
It would have been interesting to add further variables such as the unemployment rate or a social security index. However, the lack of data has prevented us from following this path and many variables have not been taken into account in order to avoid the problem of "listwise deletion". In fact, since we work with balanced panels, an entire record is excluded from analysis if any single value of a variable is missing, that is, it would lead to a reduction of N. In particular, the loss of observation units would have concerned the cancellation of municipalities belonging to pivotal areas, quite critical for the development of the State, as are those located within the geographical area of the Tucuruì micro-region. The variables excluded from the analysis are (Figure 3):

- the percentage of the population living in permanent private households with garbage collection service (T_LIXO), with 56 n.a. for the year 1991, out of which 6 are part of the region of Tucuruì.
- the unemployment rate (T_DES), with 38 n.a. in 1991, out of which 4 are part of the Tucuruì region.
- the activity rate (T_ATIV) with 38 n.a. in 1991, out of which 4 are part of the region of Tucuruì
- the rate of urbanization (T_URB) with 38 n.a. in 1991
- the rate of participation in elections (T_ELEITOR) with 14 n.a. in 1991
- the percentage of homicide per 100,000 inhabitants (T_OMI) as a security index, which presents 80 n.a. in 1991, 70 n.a. in 2000 and 26 n.a. in 2009 (there are no data for 2010).

Figure 3. Variables that could not be taken into accountSource: Personal elaboration from

Percentage of the population living in urban households with a rubbish collection service	T_LIXO	Ratio of the population living in households with rubbish collection and the total resident population in permanent private households multiplied by 100. Included the situations in which the collection of rubbish is carried out directly by a public or private company, or the rubbish is deposited in a bucket, tank or deposit outside the home, for later collection by the service provider. Only permanent private households located in an urban area are considered.
Activity rate of persons aged 10 years and over	T_ATIV	Ratio of the population aged 10 or older than 10 who were economically active, i.e. who were employed or unemployed in the Census reference week, and the total number of people in this age group, multiplied by 100. One considers as unemployed a person who was not employed in the reference week and who had been looking for work in the month prior to the survey.
Unemployment rate of the population aged 10 years and over	T_DES	Percentage of the economically active population (EAP) in this age group that was unemployed, that is, that was not employed in the week prior to the date of the Census but had sought work during the month prior to the date of this survey.
Electoral participation rate	T_ELEITOR	Ratio between the number of voters who turned up at the polling stations in the first round and the total number of voters, i.e. the electorate, multiplied by 100.
Rate of urbanization	T_URB	Ratio between the number of people living in urban areas and the total resident population, multiplied by 100.

Source: Personal elaboration UNDP, FJP, IPEA, 2013

The correlation index between 0 and 1 excludes the hypothesis of a correlation between regressors, so it is used to verify the correlation in pairs first for each of the three years (1991, 2000 and 2010) and then for the whole panel, including the water access proxy of both specifications (T_BANAGUA and T_AGUA). The variables ESPVIDA and Y_pro_cap are also considered in the procedure, although are excluded from the model because they are used for the construction of the dependent variable. The variable T_URB is also considered, to verify its possible correlation with T_AGUA/BANAGUA and T_LUZ.

In 1991, the highest correlation is 0.73 between the two main variables of housing quality, T_LUZ and T_AGUA, but all other pairs have indexes <|0.73| (Figure 4). In 2000 T_LUZ shows the highest index (0.8) in relation to the rate of urbanization (Figure 5). In 2010, the variable T_LUZ shows the highest index in relation to both of the water access variables, nevertheless lower than it was in 2000 (Figure 6). Finally, in the data panel check, the highest correlation index is between the variable T_LUZ and the two water access variables, with a stronger relationship in the case of T_BANAGUA (the same way as in 2010) (Figure 7). Eventually, we can affirm that he correlation between regressors does not affect multicollinearity.

Figure 4. Correlation matrix (1991)

	T_BANAGUA	T_AGUA	T_LUZ	T_DENS	E_ANOSESTUDO	T_ANALF	GINI	ESPVIDA	Y_pro_cap
T_AGUA	0,935								
T_LUZ	0,708	0,735							
T_DENS	-0,358	-0,309	-0,357						
E_ANOSESTUDO	0,470	0,514	0,555	-0,320					
T_ANALF	-0,508	-0,593	-0,599	0,237	-0,693				
GINI	0,260	0,244	0,211	-0,413	0,151	-0,103			
ESPVIDA	0,348	0,313	0,183	-0,229	0,290	-0,393	0,159		
Y_pro_cap	0,569	0,516	0,500	-0,605	0,233	-0,324	0,469	0,459	
T_URB	0,667	0,634	0,620	-0,171	0,412	-0,499	0,150	0,260	0,400

Source: Personal elaboration from UNDP, FJP, IPEA, 2013

Figure 5. Correlation matrix (2000)

	T_BANAGUA	T_AGUA	T_LUZ	T_DENS	E_ANOSESTUDO	T_ANALF	GINI	ESPVIDA	Y_pro_cap
T_AGUA	0,888								
T_LUZ	0,794	0,768							
T_DENS	-0,545	-0,322	-0,444						
E_ANOSESTUDO	0,750	0,671	0,738	-0,521					
T_ANALF	-0,618	-0,654	-0,598	0,321	-0,792				
GINI	0,092	0,043	0,099	-0,244	0,059	-0,090			
ESPVIDA	0,426	0,368	0,237	-0,287	0,383	-0,435	0,059		
Y_pro_cap	0,679	0,524	0,444	-0,640	0,435	-0,403	0,382	0,504	
T_URB	0,798	0,716	0,808	-0,442	0,684	-0,542	0,096	0,364	0,528

Source: Personal elaboration from UNDP, FJP, IPEA, 2013

Figure 6. Correlation matrix (2010)

	T_BANAGUA	T_AGUA	T_LUZ	T_DENS	E_ANOSESTUDO	T_ANALF	GINI	ESPVIDA	Y_pro_cap
T_AGUA	0,678								
T_LUZ	0,747	0,696							
T_DENS	-0,632	-0,753	-0,588						
E_ANOSESTUDO	0,661	0,511	0,699	-0,459					
T_ANALF	-0,660	-0,469	-0,547	0,275	-0,745				
GINI	-0,370	-0,284	-0,413	0,207	-0,348	0,306			
ESPVIDA	0,465	0,165	0,181	-0,221	0,275	-0,350	-0,099		
Y_pro_cap	0,754	0,495	0,522	-0,556	0,484	-0,516	-0,035	0,576	
T_URB	0,665	0,441	0,569	-0,408	0,535	-0,497	-0,231	0,365	0,725

Source: Personal elaboration from UNDP, FJP, IPEA, 2013

Figure 7. Correlation matrix (panel)

	T_BANAGUA	T_AGUA	T_LUZ	T_DENS	E_ANOSESTUDO	T_ANALF	GINI	ESPVIDA	Y_pro_cap
T_AGUA	0,877								
T_LUZ	0,801	0,812							
T_DENS	-0,705	-0,707	-0,673						
E_ANOSESTUDO	0,782	0,788	0,787	-0,650					
T_ANALF	-0,681	-0,683	-0,768	0,562	-0,798				
GINI	0,054	0,073	0,187	-0,238	0,073	-0,186			
ESPVIDA	0,659	0,753	0,687	-0,653	0,654	-0,720	0,239		
Y_pro_capite	0,751	0,598	0,593	-0,700	0,550	-0,538	0,292	0,595	
T_URB	0,672	0,515	0,686	-0,473	0,572	-0,602	0,149	0,468	0,611

Source: Personal elaboration from UNDP, FJP, IPEA, 2013

3.3. Model Selection

Given our data panel, to understand what kind of individual (or specific) effect we have to deal with, we apply the Hausman test adapted to spatial models, whose null hypothesis entails that there is no correlation between the individual effects and the regressors of the model (Millo and Piras, 2012). If the null hypothesis is valid, then the best model is the RE model. However, in the presence of sufficiently low p-values (as shown in Figure 8) the empirical evidence is in favour of rejecting the null hypothesis and using a more appropriate model with fixed effects.

Figure 8. Hausman test for spatial panel

	Specification 1		Specification 2	
	Kapoor et al. (2007)	Baltagi et al. (2003)	Kapoor et al. (2007)	Baltagi et al. (2003)
Value	80,605	56,535	305,32	253,11
P-value	0,0000000001	0,0000062020	0,0000000000	0,0000000000

Source: Personal elaboration from Millo and Piras, 2012

The result of the test confirms what has already been stated theoretically, namely that in our case, the choice of a FE model is supported by the fact that our sample of observations is exhaustive. It should also be noted that, unlike in the case of RE, it is not relevant here to distinguish between the error structure of Baltagi et al. (2003) and that of Kapoor et al. (2007). In fact, from an empirical point of view, the "within" transformation eliminates the individual effects, making the two specifications indistinguishable (Millo and Piras, 2012).

As we have already said, three types of interaction effects can explain why an observation associated with a specific location may depend on an observation located elsewhere. In general, the General Nesting Spatial model (GNS) includes all possible types of interactions (Fgure 1). According to Elhorst (2014) the literature is mainly interested in the application of SAR (interaction between dependents) and SEM (spatial correlation between error terms) as well as SAC models (which combine the two previous interaction effects), since models that consider the exogenous interaction do not present relevant issues to the deepening of the theories and techniques of spatial econometrics (Elhorst, 2014). Also according to the Author the literature mainly focuses on the application of models that take into account one or at most two spatial interactions at a time (e.g. respectively SAR, SEM and SAC), because the GNS is likely to result in overparameterization (Elhorst, 2014). Therefore, in line with the Author's suggestions, we have tried to take into account both the interactions between dependents and the spatial correlation of error terms. However, the interaction between dependents has always been non significant, leading us to eliminate it from the analysis, leaning towards the application of an SEM model.

In order to support our choice, we propose here the results of three tests suggested by Baltagi et al. (2003)[66] for each of our specifications (Figure 9). First we present the joint LM test (1), which tests the basic hypothesis of absence of both individual random effects (μ) and spatial correlation (λ), under the alternative that at least one of the two components is null:

$$LM_h \quad H_0: \lambda = \sigma_\mu^2 = 0 \tag{1}$$

The test confirms the presence of spatial correlation but, since it is a joint test, it produces an ambiguous result suggesting the presence of individual random effects (hypothesis that has been already tested and rejected by the Hausman test).

We perform then the marginal LM test (2), in which we test the absence of spatial correlation (λ) this time given the absence of individual random effects (μ), under the two-sided alternative hypothesis that the spatial correlation is different from zero:

$$LM_2 \quad H_0: \lambda = 0 \text{ given } \sigma_\mu^2 = 0 \tag{2}$$

According to Millo and Piras (2012), when one use this type of test, one is definitely assuming *a priori* the absence of individual random effects and that could induce an incorrect inference. For this reason we eventually perform the conditional LM test (3), by which we test the null hypothesis of absence of spatial correlation (λ) assuming the possible existence of individual random effects (μ), under the alternative hypothesis that the coefficient of spatial correlation is different from zero:

$$LM_\lambda \quad H_0: \lambda = 0 \text{ whit alternatively } \sigma_\mu^2 = 0 \text{ or } \sigma_\mu^2 \neq 0 \tag{3}$$

66 Since the choice of the best feasible model depends on the presence of spatial correlation, Baltagi et al. (2003) propose five types of Lagrange Multiplier (LM) tests by which they to test each combination of spatial correlation and individual effects.

Figure 9. Tests for spatial interaction effects

	Specification 1			Specification 2		
	LM h	LM 2	LM λ	LM h	LM 2	LM λ
Value	68,821	5,2716	5,0323	98,359	6,8493	6,7507
p-value	0,00000000	0,00000014	0,00000048	0,00000000	0,00000001	0,00000001

Source: Personal elaboration from Millo and Piras, 2012

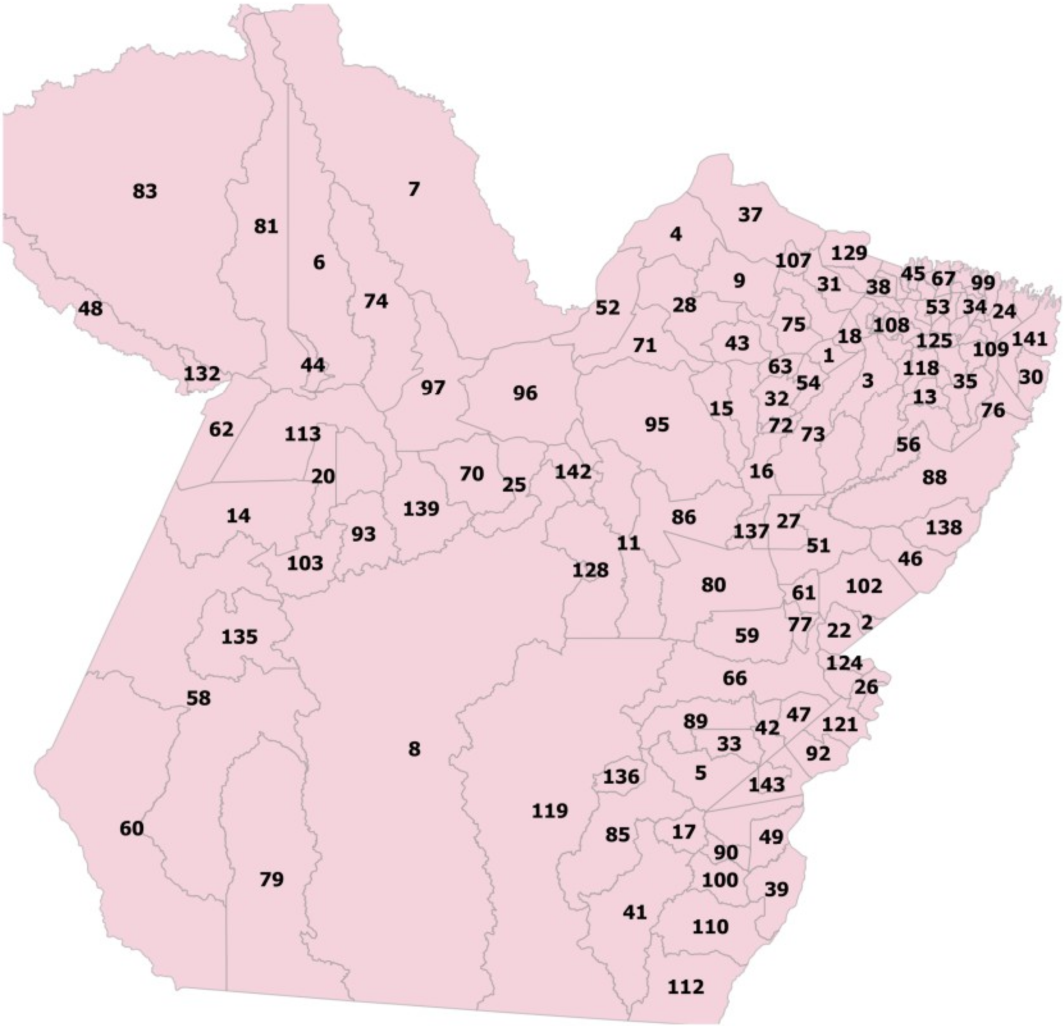
Therefore, without rejecting the presence of fixed effects (theoretically justified and confirmed by Hausman's test), we can affirm that we are going to apply a model for panel data with fixed effects in the presence of verified spatial correlation.

3.4. Model estimation

Starting from the tests performed in the previous paragraphs, we run an econometric spatial model for FE with N=143 and T=3 in which the error terms are spatially correlated. This type of model we assume that the unknown determinants of the process have a spatial correlation, as in the case of geographical variables, or that they are simply subject to spatial contagion through the market, culture or any other type of institutional mechanism (Reis, 2014). A key element of spatial data panel models is the matrix of distances W matrix, which is a NxN non-stochastic, symmetric and non-negative matrix, with all diagonal elements equal to zero. It describe the spatial configuration of the sample and due to this it must be known and it can't be estimated[67] (Elhorst, 2014). The spatial configuration matrix can present different structures: here we use a 1-order binary contiguity matrix, that is, only first-order neighbors are considered. The contiguity rule is is based on the borders in common, which can be frontier lines or just corners (Figure 10). The w_{ij} elements indicate the intensity of the relationship between cross-sectional units where $w_{ij}=1$ means neighbors while $w_{ij}=0$ means non-neighbors.

67 cf. footnote 1

Figure 10. Contiguity map of Pará



Source: Personal elaboration from IBGE

We are going to estimate a spatial panel data model by using the formulation proposed by Elhorst (2014) in which λ is the spatial correlation, μ is the specific effect and ε is the well-behaved error term:

$$y=\left(\iota_T \otimes I_N\right)\mu+X\beta+u$$

$$u=\lambda\left(I_T \otimes W_N\right)u+\varepsilon \qquad (4)$$

Elhorst (2014) starts from the Log-Likelihood function (5):

$$L=\frac{-NT}{2}\ln\left(2\pi\sigma_{\varepsilon}^{2}\right)+Tln\left|B_N\right|-\frac{1}{\left(2\sigma_{\varepsilon}^{2}\right)}e^{T}\left[I_T\otimes B_N^T B_N\right]e \tag{5}$$

with $e=y-X\beta$ and $B_N=\left(I_N-\lambda W\right)$. Then develops an iterative procedure in which provide an ML estimation of β (6) and σ (7) from first order conditions, given λ :

$$\beta=\left[X^T\left(I^T\otimes B_N^T B_N\right)X\right]^{-1}X^T\left(I_T\otimes B_N^T B_N\right)y \tag{6}$$

$$\sigma_e^2=\frac{e(\lambda)^T e(\lambda)}{NT} \tag{7}$$

Then one include the ML estimation of β and σ within the original Log-Likelihood function in order to obtain the concentrated Log-Likelihood (8):

$$L=C-\frac{NT}{2}\ln\left[e(\lambda)^T e(\lambda)\right]+T\ln\left|B_N\right| \tag{8}$$

Starting from the maximization of concentrated Log-Likelihood function with respect to λ, is it possible to obtain a ML estimation of the parameter of the spatial correlation. This value can be used to obtain new first order conditions from the Log-Likelihood function with the aim to re start the process until convergence.

4. Discussion

4.1. Descriptive statistics

The MHDI of Pará in 2010 is 0.646. According to the development bands used by the Atlas of Human Development of Brazil 2013 (UNDP, IPEA, FJP), the state is in the middle development band, having improved its position compared to previous years when it recorded low development (0.518 in 2000) and very low development (0.413 in 1991). Between 1991 and 2010, Pará gained +0.233 points, a result in line with that of the North region, although slightly below the average[68]. However, it is totally unsatisfactory when compared to the Country, which went from very low development (0.493 in 1991) to medium development (0.612 in 2000) until reaching the high development band (0.727 in 2010). In figures, although the total relative growth of +56% in the period considered was greater than that of Brazil (+47%), Pará is still at a lower level of development.

If we analyze the highest MHDIs at the end of the period considered, that is, in 2010, eight out of ten largest indices of MHDI in the State belong to large cities or metropolises (with a population approximately higher than 50,000 inhabitants)[69], including the capital Belém and its former district Ananindeua, nowadays an independent city. In general, by breaking down the human development index into its three components measured by sub-indices, it is possible to see that there is a better performance for the sub-indicator of health and a worse performance for the sub-indicator of education if compared with the income sub-indicator, which is in turn perfectly in line with the level of human development (Figure 11) .

Conversely, if we focus on the last 10 municipalities by MHDI (Figure 12) we see that only two cities are close to the size of large cities. However, as with the first ten, the best performance is that of longevity, while the score in education is lower than that of income in all cases considered. It is interesting to note that in 2010, according to the report on Human

68 The North region has in 1991, 2000 and 2010 respectively very low development (0.416), very low development (0.527) and average development (0.667) (UNDP, IPEA, FJP, 2016).

69 The size categorisation of municipalities is made on the basis of quartiles (personal elaboration from IBGE data). Towns have up to 17,044 inhabitants; large towns from 17,045 to 27,454; cities from 27,455 to 51,463; large cities and metropolises from 51,464 to 1,393,399.

Development in the Brazilian Macro Regions 2016 (UNDP, IPEA, FJP), the municipality of Melgaço has the lowest MHDI not only in the Nort Region but also in Brazil.

Figure 11. The 10 municipalities with the highest score of MHDI in 2010

The 10 municipalities with the higest score of MHDI in 2010

Municipalities	Total Population 2010	MHDI 2010	MHDI Income 2010	MHDI Longevity 2010	MHDI Education 2010
Belém	1.393.399	0,746	0,751	0,822	0,673
Ananindeua	471.980	0,718	0,684	0,821	0,658
Parauapebas	153.908	0,715	0,701	0,809	0,644
Santarém	294.580	0,691	0,632	0,807	0,648
Marituba	108.246	0,676	0,621	0,793	0,628
Canaã dos Carajás	26.716	0,673	0,670	0,801	0,569
Castanhal	173.149	0,673	0,654	0,800	0,582
Novo Progresso	25.124	0,673	0,709	0,828	0,519
Redenção	75.556	0,672	0,674	0,804	0,561
Marabá	233.669	0,668	0,673	0,785	0,564

Source: Personal elaboration from IBGE and UNDP,IPEA&FJP

Figure 12 . The 10 municipalities with the lowest score of MHDI in 2010

The 10 municipalities with the lowest score of MHDI in 2010

Municipalities	Total Population 2010	MHDI 2010	MHDI Income 2010	MHDI Longevity 2010	MHDI Education 2010
Melgaço	24.808	0,418	0,454	0,776	0,207
Chaves	21.005	0,453	0,516	0,769	0,234
Bagre	23.864	0,471	0,481	0,777	0,28
Cachoeira do Piriá	26.484	0,473	0,449	0,779	0,303
Portel	52.172	0,483	0,513	0,767	0,286
Anajás	24.759	0,484	0,506	0,774	0,29
Afuá	35.042	0,489	0,485	0,774	0,311
Ipixuna do Pará	51.309	0,489	0,508	0,757	0,304
Curralinho	28.549	0,502	0,508	0,769	0,323
Nova Esperança do Piriá	20.158	0,502	0,482	0,757	0,346

Source: Personal elaboration from IBGE and UNDP,IPEA&FJP

In conclusion, the value of the MHDI seems to have a strong direct relationship with per capita income, as the indicators of health (very positive) and education (very negative) compensate each other.

4.2. General results

To analyze the relationship between accesses and human development at the municipal level in the state of Pará during the period of the three censuses 1991, 2000 and 2010, it is possible to estimate the model on the basis of two different specifications. The first specification uses the availability of piped water and sanitation as a proxy of access to water (T_BANAGUA). In the second, less restrictive specification, just the availability of piped water is considered as a proxy of access to water (T_AGUA).

Figure 13. Determinants of municipal development in Pará

	Specification 1				Specification 2			
	ML	Std. Error	t-value	Pr(>|t|)	ML	Std. Error	t-value	Pr(>|t|)
intercept	0.333710	0.021495	15525	< 2.2e-16 ***	0.338278	0.022678	14917	< 2.2e-16 ***
λ	0.075210	0.011328	6.6392	3.153e-11 ***	0.086557	0.010521	8.2274	< 2.2e-16 ***
T_BANAGUA	7.6398e-04	1.2279e-04	6.2216	4.920e-10 ***	-	-	-	-
T_AGUA	-	-	-	-	0.00029338	0.00010906	2.6902	0.007141 **
T_DENS	-7.6926e-04	1.8976e-04	-4.0539	5.038e-05 ***	-0.00088321	0.00019674	-4.4891	7.151e-06 ***
T_LUZ	3.6936e-04	9.7865e-05	3.7742	0.0001605 ***	0.00033682	0.00010692	3.1501	0.001632 **
E_ANOSESTUDO	8.0248e-03	1.3709e-03	5.8535	4.813e-09 ***	0.00924178	0.00139075	6.6452	3.029e-11 ***
T_ANALF	-1.9401e-03	2.5046e-04	-7.7463	9.460e-15 ***	-0.00167901	0.00025660	-6.5432	6.021e-11 ***
GINI	5.6635e-02	1.6855e-02	3.3603	0.0007787 ***	0.04663674	0.01721852	2.7085	0.006758 **
factor(Year)2000	7.4013e-02	4.3722e-03	16.9279	< 2.2e-16 ***	0.07805402	0.00471293	16.5617	< 2.2e-16 ***
factor(Year)2010	1.5646e-01	7.4047e-03	21.1295	< 2.2e-16 ***	0.16385714	0.00814699	20.1126	< 2.2e-16 ***
Obs				143				143

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Note: Spatial static model for balanced panel for 143 municipalities observed in 1991, 2000 and 2010. FE=fixed effect

Both estimated models suggest that in a static panel with FE the hypothesis of a relationship between human development and access to energy/water is confirmed (significant λ) (Figure 13). The relationship is confirmed in both specifications since the parameters of T_AGUA, T_BANAGUA and T_LUZ are all significant and positive, suggesting a positive effect on development, with higher levels of significance in specification 1 than 2. T_AGUA and T_LUZ have a very similar effect in the second specification, while the coefficient of water access is higher in absolute value than that of energy access when we also control for sanitation. The negative and significant coefficient of both home population density and illiteracy, on the other hand, suggest a negative effect on the development of these variables, as expected. Finally, in support of the descriptive statistics on the MHDI (Figure 11 and Figure 12), the education shows the greatest coefficients of the model in absolute values, all significant in both specifications. The two “factor(year)” variables are included to control for the year effect, *ceteris paribus*. The only counter-intuitive result is the one performed by inequality, for which a positive and significant coefficient suggests a positive role of income inequality on human development, which needs to be analyzed in the next paragraph.

4.3. The issue of inequalities

According to Figure 13, the coefficient of Gini index is the only variable that presents a counter-intuitive result, different from what we would have expected. However, this result does not necessarily represent a model error but rather can be read in the light of a substantial literature that has developed from the contribution of Kuznets (1955). Kuznets' hypothesis is based on the fact that inequalities in income distribution have a non-linear "U" shaped relationship with economic growth. According to this relation, income inequality is positive in the initial phase of economic development and negative in the more advanced phases, being subject to the impact of the industrialization process and considering the participation of the agricultural sector in the creation of economic wealth as a proxy for development (Kuznets, 1963). Robinson (1976) supports Kuznets' thesis that the increase in inequalities in the early stages of economic development depends on the transfer of labour force from the agricultural sector to the industrial one. The author argues that since the agricultural sector is characterized by low per capita income and little inequality, when we move to a greater contribution of the industrial sector to the production of economic wealth, inevitably the inequalities increase in accordance with the characteristics of the new sector[70]. In relation to the descending part of the Kuznets curve, where economic development would then take on the task of reducing inequalities, Acemoglu and Robinson (2002) underline the role of economic reforms, in line with Kuznets' approach of "legislative decisions" affecting rents, income taxes, full employment, economic benefits and social security. Moreover, the

70 John Maynard Keynes, with reference to the beginning of the 19th century, states that "The social and economic organization of Europe was such as to guarantee the maximum accumulation of Capital. It was precisely the inequality of the distribution of wealth that made possible the enormous accumulations of fixed wealth and the increases in capital [...] the immense accumulations of fixed capital that for the great benefit of mankind were created in the half century before the war could never have taken place in a society where wealth had been divided equally. This was precisely the main justification for the capitalist system". (The Economic Consequences of Peace, 1919).

hypothesis in which economic agents invests in the presence of low inequality to favour the economic process without waiting for social conflict is approached as unrealistic since empirical evidence shows that it is the precisely social conflict that induces economic reforms (Acemoglu and Robinson, 2002).

Bearing in mind that the MHDI, while being a development indicator that provides a broader measure than just an indication of economic growth, is also built on the basis of per capita income, the positive relationship between the GINI index and the MHDI resulting from the model presented can be read in the light of critical literature compared to the classic approach à la Kuznets. On the one hand, the criticism of the Kuznets approach proposes the concept of path dependence, according to which the socio-institutional bases on which the accumulation processes are based remain over time, influencing the present and the future, even in the presence of high levels of growth. Piketty (2000) speaks of inheritance to describe the phenomenon that if the rate of return of capital is higher than the rate of growth of the economy, the rents (the so-called inheritances) grow faster than the proceeds of labour, maintaining and sometimes exacerbating the inequalities conceived in the past. On the other hand, Tribble (1999) proposes an extended approach to the Kuznets approach, according to which the reversal of the trend of inequality with respect to economic growth occurs at every economic revolution, not only in conjunction with the shift of labour force from agriculture to industry, which occurs in industrial revolutions. From here Tabosa et al. (2014), inferring the existence of more than one turning point, test the alternative formulation of the Kuznets curve as an inverted "S", in which a recovery of inequality is cyclically contemplated.

In relation to the Brazilian case, several authors have attempted to test the empirical evidence of the inverted "U" relationship between inequality and economic development with discordant results. At the level of the federated states, dos Santos et al. (2017) confirm the existence of the "U" relationship only in the long term, while in the short term the relationship has an "S" behaviour. They also demonstrate that 28.6% of the inequality captured for the period 1992-2010 is made up of what they call the inertial component. Rodrigues et al. (2016) propose two different specifications, based respectively on the Gini index and on the Theil index. In both cases, they reject the hypothesis of the inverted "U" when tested in a basic model that does not take into account additional variables as possible channels of transmission of inequality. At the level of municipalities instead, from da Silva Junior et al. (2016) we get a positive empirical evidence, but the analysis is carried out with the municipalities of Santa Catarina, one of the federal states with the highest level of growth in the country, at the antipodes with the state of Pará.

4.4. How to manage the fixed effects

In general, the estimation of fixed effects may not be consistent in the case of large N and small T. In fact, for a large number of cross-sectional observations (N=143) occurs the incidental parameter problem. However, estimates of individual effects in a fixed effect model may be consistent when T is large enough because the number of useful observations available to estimate each individual effect μ_i is T (Baltagi, 2008). In the presented model, where the cross-section dimension is N=143, while the time series dimension is T=3, estimates of fixed effects should be interpreted with caution[71].

Furthermore, it appears that only 14 out of 143 units shows significant estimates of fixed effects:

Figure 14. Significant FE in Specification 1 and Specification 2

Municipalities with significant fixed effect							
Code	ID	FE 1	FE 2	GDP per capita in BR$(2015)	% of external revenue (2015)	Rank GDP per capita within Pará (2015)	Rank % of external revenue within Pará(2015)
1	Abaetetuba		0.05222802	7960,05	0,931	91	40
5*	Água Azul do Norte	-0.056354	-0.05396657	14446,4	0,95	32	27
7	Almeirim		0.05330900	19014,17	0,93	19	41
8	Altamira		0.04999446	29710,79	n.a.	6	n.a.
10*	Ananindeua	0.071803	0.09567793	12339,62	0,772	43	74
18*	Barcarena	0.059728	0.07273698	47684,37	0,71	4	75
19*	Belém	0.088827	0.11732983	20340,21	0,588	17	79
31	Cachoeira do Arari		-0.05940579	7099,77	n.a.	105	n.a.
34	Capanema		0.04697022	14477,88	0,824	31	69
37	Chaves		-0.05193617	7457,48	0,964	100	11
66	Marabá		0.04724986	27956,09	0,705	7	76
89*	Parauapebas	0.052498	0.06649864	59018,97	0,809	2	70
108	Santa Izabel do Pará		0.05631732	9196,28	0,906	65	53
113*	Santarém	0.048252	0.05814171	13606,9	0,831	37	66

* Municipalities with significant FE in Specification 1

** All municipalities in the table have significant FE in Specification 2

Source: Personal Elaboration from PNUD/IPEA/FJP,2013; IBGE, 2018.

71 It is noteworthy to remember that inconsistent estimates of individual effects do not affect β estimates.

In order to understand whether and to what extent the FEs may assist in studying the human development dynamics ad municipal level, a socio-economic in-depth analysis can be of help. In fact, the municipalities that have significant estimates of individual effects have some common features such as economic and geographical proximity to the capital city (the capital city itself has a significant individual effect), the presence of natural resources and the presence of companies related to the exploitation of these resources. The city of Belém, capital of the state of Pará, was founded in 1616 starting from the exploitation of rubber, a very profitable activity in the Amazon area. Its main activities are nowadays related to public administration and services. National and international trade is an important activity, so much so that it is the seat of *ver-o-peso*, one of the oldest and most important ports and markets in Latin America. The administrative organization of Abaetetuba, Ananindeua, Barcarena and Santa Isabel do Pará are historically linked to the development of the capital. Ananindeua and Abaetetuba (respectively "city of dwarf trees" and "city of illustrious men", in Tupi language), originally districts of Belém, became autonomous municipalities only in 1943; Santa Isabel instead, originally district of the Capital, became an autonomous municipality in 1961 (IBGE, 2018). Barcarena, until 1937, was also part of the municipality of Belém, but it was not only the proximity to the capital that favoured its growth. In fact, its name derives from a large boat docked in its harbour, the Harbour of Vila do Conde, one of the main commercial ports of the Amazon whose expansion and enhancement dates back to the project of national interest *Grande Carajás*[72], developed in the '80s.

In addition to their proximity to the economic and administrative centre of the State, seven other municipalities have common characteristics since they are all benefit from the presence of natural resources (water or precious minerals), to which the industrial development of the related sectors is linked, sometimes associated with public funding programmes such as the aforementioned *Grande Carajás Programme* (IBGE, 2018). Parauapebas and Marabá are both located in the area of the *Serra Carajás*, a huge ore reserve from which the abovementioned national programme of the '80s took its name. Água Azul do Norte, on the other hand, is not directly affected by the ore reservoir, but its administrative history sees it linked to the

72 The programme was officially established by Decree-Law No. 1831 of 21 October 1980, which established a special scheme for granting tax and financial incentives for investments located in an area of 90 million hectares, divided as follows: 53 million hectares belonging to the state of Pará, 31 million hectares in the state of Maranhão and 9 million hectares in the state of Goiás. The programme included specific projects: the Carajás iron mine, the Albrás-Alunorte refinery, the Tucuruí hydroelectric plant, the Carajás-São Luiz motorway and the Porto de Vila do Conde (in Barcarena).

municipality of Parauapebas until its emancipation as an autonomous municipality in 1991. Likewise, in addition to its impressive dairy production, Almeirim bases its economy on the mining of bauxite (aluminium oxide, the basis for the production of aluminium) and kaolin. Barcarena, on the other hand, in addition to being linked by its geographical proximity and administrative affairs to the capital, is the headquarters of the aluminium multinational enterprise Hydro Alunorte[73]. Finally, in Capanema, one of the cities with the highest GDP in the region, a profitable economic opportunity is represented by the extraction of halide (DataViva, 2018).

Extraction activities also play an important economic role in Altamira which, thanks to the presence of abundant water resources, since 2010 has become the headquarter of an important hydroelectric power station, the Belo Monte power plant. The city of Santarém also hosts a hydroelectric power plant, the Silvio Braga power plant, as well as standing out for the production of mandioca and its Ecotourism.

Cachoeira do Ararí, a city of agriculture and fishing, and Chaves, famous for its craftsmanship, also have significant individual effects. However they have no common characteristics to any of the other municipalities described above neither in terms of the economy nor of geography.

The individual effect, if positive, captures the influence that the specific characteristics of the individual municipalities observed have in increasing the value of their municipal human development index. Therefore, although it is observed that none of the selected municipalities is in the high human development range, it is worthy to observe that all the municipalities with significant specific effects are at a medium/high level of human development, except for Chaves, Cachoeira do Ararí and Água Azul do Norte (which, as a matter of fact, have negative individual effects)(Figure 14). In particular, Chaves, whose effect is negative, is the second to

73 The multinational enterprise Hydro Alunorte is present in Barcarena in a dual way. On the one hand, it has been operating since 1995 through the Alunorte - Aluminio do Brasil S.A. refinery industry, transforming the raw material coming mainly from Paragominas and Trombetas; on the other hand, it participare through the acquisition of 51% of the company ALBRAS - Aluminio Brasileiro S/A, which has been the second largest aluminium producer in Brazil since 1985. Most of the refined product from Alunorte directly supplies ALBRAS, originally a Japanese company, now only by 49%. The strengthening of the Brazilian aluminium industry through the growth of ALBRAS, whose main source of energy is hydroelectric power produced at the Tucuruí plant, was one of the objectives of the *Grande Carajás* programme, together with the construction of the Tucuruí hydroelectric power plant.

last municipality in the state of Pará by human development index, just before Melgaço, the municipality with the lowest human development index of Brazil (Figure 12).

Figure 15. MHDI of municipalities with significant FEs in 2010

Achievements in human development by the 6 municipalities (code) with statistically significant FE in Specification 1					
HD range*		MHDI (2010)	MHDI income (2010)	MHDI longevity (2010)	MHDI education (2010)
Very high	0,800 - 1,000	-	10;18;19;89;113	10;18;19;89;113	-
High	0,700 - 0,799	10;19;89;113	-	5	-
Medium	0,600 - 0,699	18	5	-	10;19;89;113
Low	0,500 - 0,599	5	-	-	18
Very low	0,000 - 0,499	-	-	-	5

Achievements in human development by the 14 municipalities (code) with statistically significant FE in Specification 2					
HD range*		MHDI (2010)	MHDI income (2010)	MHDI longevity (2010)	MHDI education (2010)
Very high	0,800 - 1,000	-	7;8;10;18;19;66;89;108;113	7;8;10;18;19;89;113	-
High	0,700 - 0,799	10;19;89;108;113	1	1;5;31;34;37;66;108	-
Medium	0,600 - 0,699	1;7;8;18;34;66	5	-	10;19;89;113
Low	0,500 - 0,599	5;31	31;37	-	1;8;18;34;66;108
Very low	0,000 - 0,499	37	-	-	5;7;31;37

* Atlas do desenvolvimento humano no Brasil 2013 (PNUD/FJP/IPEA)

Source: Personal elaboration from IBGE, FJP, IPEA.

It should be also noted that, by breaking down MHDI by sub-components according to the calculation proposed by UNDP/FJP/IPEA (2013), it is clear that it is the values relating to education that undermine the measurement of human development as a whole, in the presence of excellent positions in terms of income and health.

Conclusions

The results of this study suggest that the impact of access to both water and energy on human development in the state of Pará is significant and positive for the period of interest. This suggests that the accesses could be valid drivers to obtain higher levels of development, given the abundance of water resources present in the area. In fact, if on the one hand its human development index is below the average of both North Region and Brazil in all three years of the census, on the other hand the state of Pará has the advantage of being located between two huge catchment areas, that of the Amazonas river and that of Tocantins river, having great amounts of water resources. It is one of the largest states in the Brazilian Amazon, almost all its municipalities are located near harbours, as far as today, river transport is a key part of the logistics of the state and its hydroelectric potential corresponds to about 80% of the water resources explored. However, if in 1991 Pará had the seventeenth lowest MHDI out of 26 Brazilian states, in 2010 it becomes the third lowest. In the light of our results, this dramatic performance clearly denounces a problem of access rather than scarcity. In particular, focusing on the problem of access to energy, there is an energy justice problem in which the three components of distribution, procedure and reconnaissance - as described by Magnani and Vaona (2016) - are not fully respected.

First of all, there is no distribution justice if there is a lack of the correct distribution of costs and benefits deriving from the application of technologies for energy production, which first of all represents an opportunity cost for the use of water. This is the case of the displacement of people due to the diversion of the river or of the damage to biodiversity or economic activity not adequately compensated (Caravaggio and Iorio, 2016). Secondly, procedural justice (which requires the use of fair and transparent decision-making procedures for the sake of the inclusion of all possible stakeholders) is lacking whenever indigenous reserves or protected areas are directly or indirectly involved by the unilateral decision that is neither shared nor duly discussed (Herrera and Moreira,2013). Finally, there is no justice of recognition when the heterogeneity of the needs of the beneficiaries is not recognized and taken into account, as in the case of lack of rural electrification (Van Els, 2012).

According to Fearnside (1999), in the process of building the Tucuruì power plant, Brazil's largest hydroelectric power plant in terms of production, all injustices described above occurred. It is no coincidence that, in terms of MHDI, the municipalities belonging to the region of Tucuruì, where the enormous amount of water allows the production of the electricity that supports the growth of the country, perform the lowest MHDI of the State.

In the light of what has been said so far and recognizing the importance of public policies in the implementation of complex technologies such as hydropower, it is believed that development policies should be oriented in the direction of restoring energy justice, bearing in mind that allocating a valuable asset such as water for energy purposes can have a very high opportunity cost even in the presence of large equipment. On the one hand, adapting compensation to the real needs arising from social and environmental changes, or limiting the increase in the cost of energy for end users are measures that can potentially be useful to re-establish a distributive justice (more than 60% is represented by the costs of transmission, cost of distribution, taxes, however just 6% is re-invested in the SIN - Sistema Interligado Nacional) (ABRADEE, 2018). The extension of the low-voltage electrical network, i.e. the one linked to domestic consumption, is pivotal to boost development in rural areas, especially when these surround large power plants (as in the micro-region of Tucuruì) and to re-establish recognition justice, making rural electrification an effective driver of development. Finally, preferring a participatory process to a top-down approach should be the fair procedure for the enhancement of both economic and human development.

To deepen the topic, it is possible to improve the methodological analysis of data in three directions: considering other types of spatial models that include different spatial correlations (e.g. the spatial exogenous correlation), through the use of different types of matrices of weights (e.g. the inverse matrix of distances, widely used in literature) and finally providing a measure of data adaptation for spatial models.

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