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Ex-post evaluation of the socio-economic consequences of the Integration Project of the São Francisco River with Watersheds of the Northern Northeast

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Abstract

This paper evaluates *ex-post* the economic and social consequences generated by the effect of the increased water supply created by the Integration Project of the São Francisco River with Watersheds of the Northern Northeast - PISF - on the beneficiary municipalities since 2017. The study finds evidence that the PISF has not increased household coverage of water supply, but it has increased the frequency of that supply, in terms of days. The positive outcomes of the PISF include an increase in livestock production, an increase in the extent of planted areas used for agricultural production, and a reduction in deaths due to diarrhea. The negative results of PISF include a reduction in formal salaries and employability in the regions benefited by the policy.

Keywords: Quality of public spending; Integration Project of the São Francisco River; Ex-post evaluation of public policies; Impact evaluation.

JEL Classification: C23, H430, H540

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1. Introduction

There is a growing demand from Brazilian society for public services. However, the government's capacity to obtain financial resources to provide public services is restricted. The solution to this problem must necessarily involve prioritizing the effectiveness, efficiency and equity of public policies. In other words, decisions on public policies must be rational, so that more can be done with less.

The most direct way to promote improvement in the quality of public spending is to conduct evaluations of public policies and suggest the formulation of new policies, or the improvement of existing policies, based on the results of the evaluations.

Additionally, with the advent of EC #95/2016, which instituted the New Tax Regime, the total amount of primary expenses cannot be increased in actual terms for 10 years. The association of this tax regime with the inflexibility of increasing mandatory expenditures resulted in a drastic reduction of public investments in Brazil in recent years. Only evaluations of public policies allow the allocation of the resources remaining for investment in the Federal Budget to the best opportunities for growth and social performance. Moreover, policy evaluations may provide concrete indications for eventual stimuli to private investments in infrastructure.

With this concern in mind, this study proposes to evaluate the largest public infrastructure project in Brazil in the last decade and the largest water project in the country's history: The Integration Project of the São Francisco River with Watersheds of the Northern Northeast - PISF. This paper evaluates *ex-post* the economic and social consequences generated by the effect of the increased water supply created by the PISF.

According to the Federal Audit Court - TCU report (2020), about R$ 17 billion have already been spent on the construction of the transposition axes. In addition, another R$ 13 billion is estimated to be spent on complementary works that interconnect the various reservoirs and dams in the region, to allow more municipalities to have a water supply regulated by the waters of the São Francisco River. Much has been discussed about the enormous costs, the justifications for the implementation of the works, and the possible effects on society. However, there is little *ex-post* evidence of their actual effects on the socioeconomic reality of the benefited population.

This study fills the gap in the lack of *ex-post* evidence of the PISF, by empirically analyzing its impacts after spending of around R$ 17 billion since 2007. This way, we intend to evaluate its efficiency and effectiveness, from the point of view of public resource allocation, as well as the convenience of its conclusion or the expansion of the PISF in complementary works in the region.

This evaluation finds preliminary evidence that the PISF has not increased water supply coverage to households not previously served by the local water supply system. However, there is evidence that PISF has increased the frequency of water supply, in terms of days. The evidence shows that the increase in permanent water supply occurred in municipalities located out of the largest urban centers, such as rural regions and out of the João Pessoa metropolitan region.

This work also finds evidence that the PISF has contributed to an increase in livestock production, an increase in the extension of planted areas used for agricultural production, and a reduction in deaths due to diarrhea, showing an improvement in the quality of regional water supply.

On the other hand, this work estimated that the PISF has negative impacts on the formal labor market in the first years of implementation. It is estimated that the PISF tends to reduce formal salaries and employability in the regions benefited by the policy. These effects, though small, are opposite to the desired effects of the policy and cited in the *ex-ante* evaluations. It should also be noted that these results are preliminary, since it was not possible to perform a global analysis of the effects of the PISF for the entire labor market due to the lack of a database.

To perform all these estimates, this study mainly implemented the Difference-in-Difference's method, which performs a double subtraction of the means between the before and after results, and between the results of the treatment and control groups. As the treatment group, the municipalities that received water from the PISF, since the first half of 2017, are considered. As the control group, two approaches are used: (1) municipalities initially eligible for the PISF, but that did not receive the PISF waters until 2019 and that there was no realization of works of the axes within their territory; (2) municipalities of control group 1 that were chosen by the *Propensity Score Matching* procedure, i.e., that present observable characteristics closer to the characteristics of the municipalities of the treatment group.

The information used comes from several databases. They are related by identifying the locations of the beneficiaries of the PISF waters, and the locations chosen as belonging to the control group. Furthermore, the databases have information from before and after the beginning of the PISF water supply. This work uses the following databases opened by municipalities: Municipal Agricultural Production, from IBGE; from the Municipal Livestock Survey, from IBGE; and from the Public Sector Accounting and Tax Information System, from the National Treasury Department. Additionally, we use the following databases with personal information, at the microdata level: The Continuous National Household Sample Survey, from IBGE; the Annual Social Information Report from the Ministry of the Economy; and the Mortality Information System, from DATASUS.

This manuscript has seven sections, including this introduction. The next section presents the PISF, makes the diagnosis of the problem and details the objectives of the policy, some of which will be evaluated at the end of the work. Subsequently, the text presents a brief literature review, its methodological details, and a description of the primary sources of information. Finally, the analysis of the results and final considerations are presented.

2. Integration Project of the São Francisco River with Watersheds of the Northern Northeast - PISF

Brazil is a country that has diverse realities in its regions. The country has a freshwater availability considered one of the largest in the world, but, at the same time, presents a huge level of water inequality among its regions. While the Amazon region concentrates 80% of the country's water surface, the Northern Northeast region has a serious water shortage problem, which hinders the sustainability of local life.

The Northern Northeast has geographical conditions that hinder water availability. The area suffers from insufficient levels of natural water reserves, high temperatures most of the year, strong sunshine, high rates of water evaporation, irregular rainfall levels of less than 900 mm per year, and long and frequent periods of drought. Putting all these local characteristics together, the Northern Northeast presents a water supply of little more than 400 m³/inhab/year, that is, almost a quarter of the minimum level of water availability recommended by the United Nations for maintaining a sustainable standard of living (1,500 m³/inhab/year).

In this context, the Integration Project of the São Francisco River with Hydrographic Basins of the Northern Northeast - PISF - is a federal government policy that seeks to solve the problem of low water availability in the region. The project aims to increase the supply of water through the transposition of the waters of the São Francisco River at an average flow rate of 65m³/s to the existing water basins.

PISF is a water infrastructure project that collects water from the São Francisco River and distributes it to several river basins in the states of Ceará, Paraíba, Pernambuco, and Rio Grande do Norte. The region benefited is known as the Northern Northeast, which encompasses the Northeastern Sertão and Agreste regions. The project is composed of two major water transfer axes and associated branches: North Axis, East Axis, Entremontes Branch, Agreste Branch, Salgado Branch, and Apodi Branch. The project was initially expected to serve 390 municipalities and a population of 12 million people. After a TCU (2020) study that updated this data, the project can serve 399 municipalities, with a population of 13.2 million people[1].

The East Axis, with 217 kilometers, had its main works completed in March 2017. Currently, this axis is in the pre-operation phase, distributing water to 52 municipalities in the states of Pernambuco and Paraíba[2], and is expected to have a maximum capacity of 28 m³/s and a continuous flow of 10 m³/s. The North Axis, with 260 km, is expected to be completed in 2021,

[1] Using the 2019 IBGE population estimate for the cities listed by the TCU (2020), this study estimates a population of 13.2 million people.

[2] After researching newspaper news and analyzing Neto and Vianna's (2016) study of working water mains, this assessment identified 52 municipalities currently benefiting from the PISF. This information is different from the website of the Ministry of Regional Development (MDR), which notifies 46 municipalities.

and will serve municipalities in Pernambuco, Ceará, Paraíba and Rio Grande do Norte. In June 2020 a stretch of the North Axis was inaugurated in the city of Jati/CE, which will take water to some cities in the state of Ceará. This Axis is planned to have a maximum capacity of 99 m³/s and a continuous flow of 16.4 m³/s. Together, the two axes will have an installed capacity of 127 m³/s, a continuous pumping flow (56% of the months) of 26m³/s and a planned average flow of 65m³/s. Considering the average regularized flow through Sobradinho of 1,825 m³/s (Pereira Jr, 2005), the continuous and average flows from the São Francisco River represent only 1.41% and 3.51% of the capacity in that stretch. This means that the PISF will have very little effect on the river flow downstream of the Sobradinho reservoir. Figure 1 presents the water distribution map of the project.

Figure 1 - General map of the PISF water infrastructure

Source: Disclosure of the former Ministry of National Integration, currently the Ministry of Regional Development (MDR).

Figure 1 shows that the North Axis passes through the municipalities of: Cabrobó, Salgueiro, Terranova and Verdejante, in Pernambuco; Penaforte, Jati, Brejo Santo, Mauriti and Barro, in Ceará; São José de Piranhas, Monte Horebe and Cajazeiras, in Paraíba. It will carry water to the Salgado and Jaguaribe rivers, in Ceará; Apodi, in Rio Grande do Norte; and Piranhas-Açu, in Paraíba and Rio Grande do Norte. In turn, the East Axis will pass through the Pernambuco cities of Floresta, Custódia, Betânia, and Sertânia; and the Paraíba municipality of Monteiro.

As the local water basins are already used by many municipalities as a source of water distribution, then the transposition of the waters of the São Francisco River to these basins will enable a permanent and stable water supply for a good part of the region's municipalities. However, one of the prerequisites of this project is to allow the basins and dams in the region to be interconnected. In this way, it is possible that a greater supply of water will reach several municipalities. Moreover, the integration of the system allows a reduction in water stored in the reservoirs, because the water from the transposition can be used to circumvent eventual local supply crises. This reduction in the surface area of dammed water will considerably reduce evaporation in the reservoirs, generating gains in water cooperation and indirectly increasing the supply of water. Farias et al. (2012) simulated a water resources optimization model with the PISF water supply for the Castanhão reservoir in Ceará. The authors estimated that the hydric cooperation gains will be equivalent to almost one third of the region's hydric demand, generating a water supply of 10m³/s in that reservoir.

The TCU Report (2020) classifies hydroelectric synergy as the increase in the supply of water resources in four ways: (i) "water guarantee" which, by optimizing the water management of reservoirs, reduces the amount of evaporated water and spilled volume; (ii) "water security", which tends to reduce existing water conflicts between water users from different river basins; (iii) "water quality improvement" of dams by renewing them more frequently and reducing salinity; and (iv) "induction of improvements in water management" by encouraging the institution of water use allocation and its charging. This last effect increases the efficiency of water use by inducing a management system that defines property rights. It aims to alleviate a problem known in economic literature as the tragedy of the commons (Hardin, 1968).

The cost of the PISF has increased considerably since the design phase and represents a high level of public resources. The estimated cost of the project in the planning phase (ENGECORPS and HARZA, 2000) was R$ 2.7 billion. However, according to a report by TCU (2020), it has already executed about R$ 17 billion. In addition, about 33 complementary works will be necessary for the supply of water from the São Francisco River to reach the targeted cities and for the water supply systems to be integrated. The forecast expenditure of these complementary works is R$ 13.2 billion (TCU, 2020). This amount makes the total cost of the PISF about R$ 30 billion, more than ten times the initial cost.

This estimate does not consider the operational cost of the PISF. This cost, initially budgeted at R$ 1.2 billion/year (TCU, 2020), was planned to be covered by charging a tariff for water use. This tariff was planned to be financed by a cross-subsidy mechanism (ENGECORPS and HARZA, 2000), where urban and industrial activities would pay part of the tariff for agricultural and rural activities. Currently, the East Axis has been running since March 2017 in the pre-operation phase, when there is no charge for water use. In other words, for three years this operating cost has been borne by the Federal Government. The situation gets worse when considering the lack of expectation about the beginning of the charging period. According to the TCU (2020), none of the states signed the management contract. "*The risk of not signing was considered by the managers with the possible probability and very strong impact* " (TCU, 2020).

The discrepancy between the planned and realized deadline was also extremely high. The initial deadline was six years of construction (ENGECORPS and HARZA, 2000). However, construction started in 2007 and should be finished in 2021, i.e., more than twice as long as originally planned. The large increases in budget and time needed for the construction of PISF demonstrate that some of the fundamental assumptions of the *ex-ante* evaluation by ENGECORPS and HARZA (2000) were strongly underestimated and questioned whether the project was economically feasible.

1.1 Problem diagnosis

The Northeast region presents great inequality in the distribution of water resources. While the basin of the São Francisco River has 70% of the entire drinking water supply in the region, with a demographic density of about 10 inhabitants/km², the Northern Northeast region has little water supply and a demographic density of about 50 inhabitants/km².

The semi-arid region has insufficient levels of natural water reserves, high temperatures most of the year, strong sunshine and, as a result, high rates of water evaporation, according to the Atlas of Urban Water Supply prepared by the National Water Agency (Brazil, 2010). Evaporation is so high that, according to ENGECORPS and HARZA (2000), only 25% of the reservoir capacity of the region can be used for water distribution. This local characteristic makes the policy of creating artificial water reservoirs inefficient, requiring an effective alternative for the local water supply.

Furthermore, rainfall levels are irregular and less than 900 mm per year, with frequent and long periods of drought and a high recurrence of the drought phenomenon. In general, the region's rainfall levels are exceeded by high evaporation rates, which leads to negative water balance rates.

Putting all these local characteristics together, the Northern Northeast presents a water supply of a little more than 400 m^3/inhab/year, made available by dams built on intermittent rivers and aquifers with limitations on water quality. While the São Francisco basin region presents a water supply of 2 thousand to 10 thousand m^3/inhab/year, made available by permanent rivers.

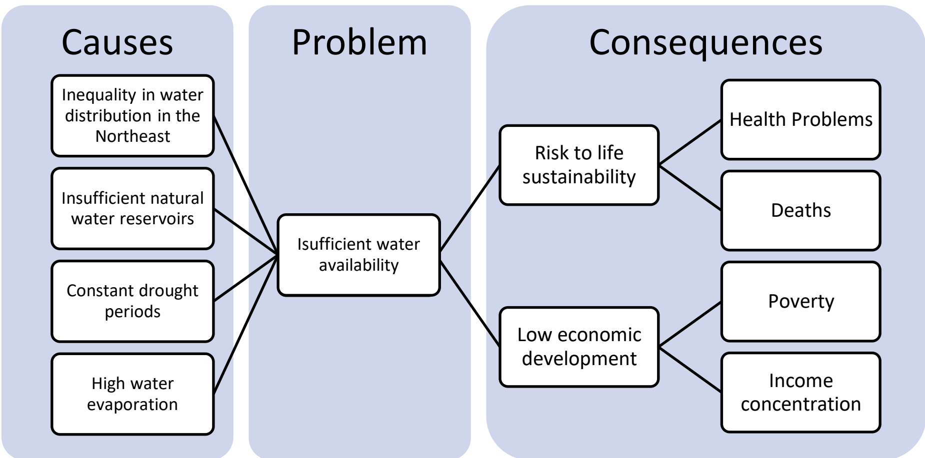
The reduced water supply constitutes a high risk for the sustainability of life in the region. According to the United Nations (UN), a minimum level of water availability compatible with the maintenance of a sustainable standard of living is 1500 m^3/inhab/year. It so happens that the Northern Northeast region has a water availability of only 400 m^3/inhab/year, that is, nearly a quarter of the minimum level recommended by the UN.

The reduced water supply and the consequent unsuitable condition for the sustainability of life in the region constitutes a bottleneck for attracting private investment and for developing economic activities.

The low level of investment and local economic attractiveness generates problems in the development of industry, services, and agricultural production in the region. This result is reflected in the low creation of jobs and job opportunities, and, in turn, has consequences on household income. The cascading effect ends up generating high income inequality and the high poverty levels of the local population. One of the indicators of this process is the high level of migration of the local population to urban centers in the Northeast and Southeast. This migratory movement is called rural exodus.

In this context, the PISF is a federal government policy that seeks to increase water availability through two mechanisms: (i) transposition of the waters of the São Francisco River at an intended average flow rate of 65m³/s to local water basins; and (ii) gains in water cooperation, mainly obtained by reducing evaporation and overflows from existing reservoirs.

Figure 2 - PISF Problem Tree
Source: own elaboration.



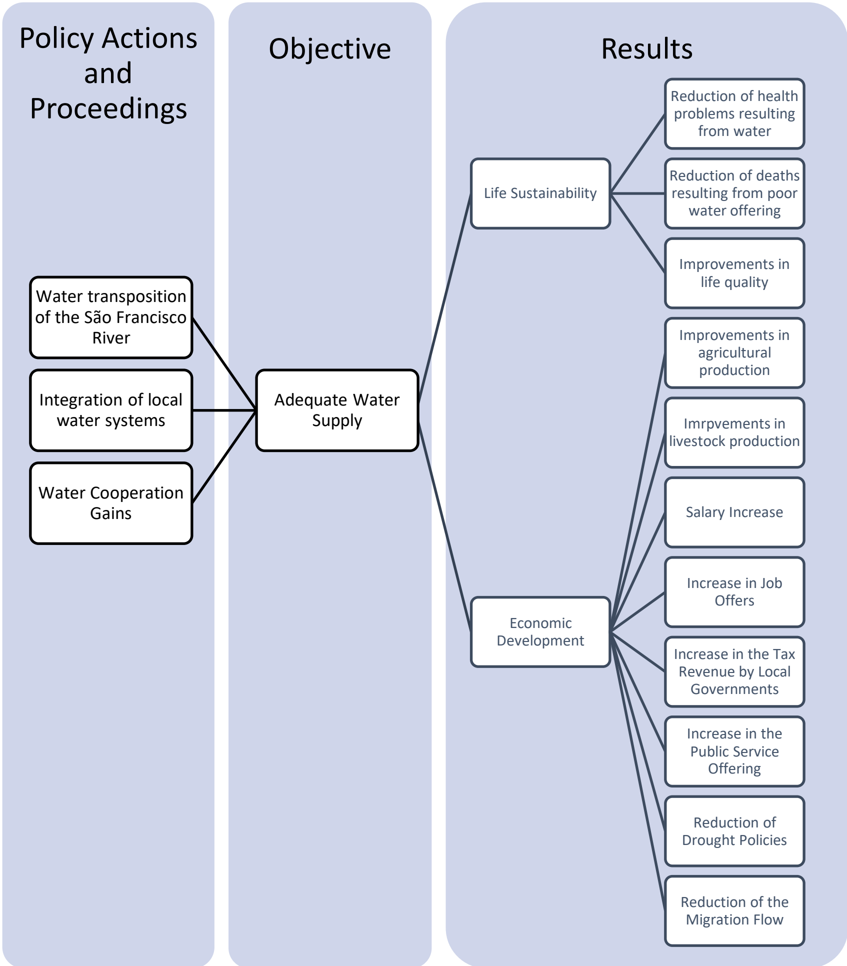
The PISF aims to interfere in this situation by increasing the availability of water, in a flexible, manageable and adequate way to meet water demand, improving the distribution of water in the Northeast and reducing water waste through gains in water cooperation. Consequently, the PISF also aims to improve the living conditions of the region's inhabitants, enable increased economic development, increase employability, income and production in the Northeast.

1.2 Public Policy Objective

The main objective of PISF, according to the ex-ante evaluation of ENGECORPS and HARZA (2000) is to "ensure an adequate supply of good quality water, with guarantee, for the population and economic activities".

This policy aims to directly solve the problem of unsatisfactory water availability in the region. As shown in Figure 2, in solving this problem, it also aims to achieve a series of secondary objectives with positive effects on the development of the local economy and the quality of life of the population. The *ex-ante* evaluation by ENGECORPS and HARZA (2000) formulated four guidelines that encompass the secondary objectives of the PISF: social and economic function; environmental sustainability; efficient management of water resources; and technological advance. ENGECORPS and HARZA (2000) estimated some of the secondary objectives in quantitative terms. But there are objectives that were only mentioned in qualitative terms. As three years have passed since the completion of the PISF East Axis, this *ex-post* evaluation aims to estimate whether some of these initially outlined objectives have in fact become effective. To understand the cause-and-effect relationship of these objectives, Figure 3 presents the PISF objective tree.

Figure 3 - PISF's Objective Tree



Source: own elaboration.

Therefore, one can highlight that the PISF aims at:

- ensure an adequate supply of good quality water;
- ensure sustainable patterns of water resource use;
- improve the geographical distribution of water resource availability within the Northeast;
- develop irrigated agriculture and reduce the effects of droughts, especially small-scale diffuse agriculture;
- develop fish farming production;
- induce efficient management of water resources, with payment of raw water quotas provided by the PISF;

- enable water cooperation through the better use of local water from strategic dams, reducing losses by evaporation and spillage;
- generate about 5,000 direct jobs with the construction of the project;
- create about 620,000 jobs with the water supply;
- increase the budget revenue collected by local governments, and in turn increase the provision of public goods and services;
- reduction of mortality rates from diseases related to lack of water or water quality; and
- reduce outbound migratory movements of people to the urban centers.

3 Literature review

Pereira Jr (2005) evaluates *ex-ante* the cost-benefit in qualitative terms of the PISF. The author concludes that environmentally and meritoriously the project is valid and justifiable. He ponders only whether its economic side would be justifiable. According to the author, there are doubts as to whether the costs would be bearable for the benefits generated by the Project.

Seeking to answer this question, ENGECORPS and HARZA (2000) prepared a comprehensive *ex-ante* evaluation of the PISF. The report describes the problem faced, maps the objectives, analyzes the alternative opportunities, describes the PISF, plans the estimated cost and timeframe of the project, and evaluates the project in terms of engineering and in terms of its economic feasibility. According to the economic feasibility study, the project has a NPV of R$ 1.8 billion and an internal rate of return of 21.9%. To estimate these results, the report considered a series of hypotheses, among them that the project would take only six years to complete and an estimated implementation cost of R$ 2.7 billion.

The original deadline was six years of construction (ENGECORPS and HARZA, 2000). However, construction started in 2007 and should be finished in 2021, i.e., more than twice as the original deadline.

By 2018, the cost of the PISF has reached astronomical results of R$ 17 billion, representing a difference in current terms of almost 14 billion. The high budget and schedule increases required for PISF construction demonstrate that some of the fundamental assumptions of the *ex-ante* evaluation by ENGECORPS and HARZA (2000) were strongly underestimated and put into question whether the project was economically viable.

Considering the actual NPV value of R$ 1.8 billion in 2019 prices, we would have an NPV value of R$ 7.5 billion. However, since the cost of the project increased by almost R$ 14 billion in current terms, then it can be stated that the project was not economically viable.

Furthermore, the study by Guimarães (2016) revisits some assumptions of the *ex-ante* evaluation and redoes some water demand and supply forecasts. According to the author, the assumptions about the percentage of loss in water distribution were 25%. However, in 2010, this percentage was 37%. Another unreasonable assumption was the percentage of water service, which was equal to 95%. In 2010 the level of service was 72% in Paraíba. When adding the financial impact of these unreasonable assumptions with the impacts of the cost assumptions of R$ 2.7 billion and the execution time of six years, one can conclude that the assumptions were optimistic and that this project would not be economically viable.

In direct opposition to the study by ENGECORPS and HARZA (2000), Castro (2010) re-examines some aspects of the *ex-ante* evaluation after the PISF has started and long before it is completed. According to the author, the PISF should not be started because (i) the benefits of the *ex-ante* evaluation were overestimated; (ii) alternative policy solutions were better; and (iii) the PISF may cause long-term damage to the economic development of the water donor region, located in the São Francisco River basin.

Some of Castro's (2010) conclusions are open to criticism. The first controversial conclusion of the author is that there is no water deficit in the Northern Northeast region. He concludes this result by analyzing information on water demand and supply, made available by the National Water Agency (ANA). However, this argument does not consider that the demand is repressed by the lack of water availability, because (i) there are periods of water rationing and offers of water tank cars and this contingent the consumption of water; (ii) the economy does not develop because there is no water infrastructure, and the demand is lower without economic development. The study by ENGECORPS and HARZA (2000) also analyzed the region's water supply and demand, and incorporated economic development scenarios in its demand projections. Furthermore, the criticism of the existence of a water deficit also disregards the UN international reference of minimum water availability for a sustainable standard of living.

Castro (2010) also argues that the population and municipalities that will be served by PISF will be a smaller number than the 390 municipalities and 12 million people previously defined. However, this argument loses force when analyzing the TCU report (2020) that re-estimated the scope of the PISF and concludes that there will be an increase in the beneficiary cities and the population benefited by the policy.

In another study, Castro (2011) evaluates whether agriculture in the Northern Northeast could be developed with the implementation of the PISF. He concludes that even with the PISF, the goal of developing agriculture is not feasible, because if there is growth in agricultural production, the flow of water demanded will be greater than the supply capacity served by the PISF. According to the author, an alternative solution would be to invest in more efficient irrigation technology for producers in the Northern Northeast.

Following the same line, Guimarães Jr (2016) also re-evaluates *ex-ante* negatively the PISF. The author also concludes that there is no water deficit in the Northern Northeast region. Furthermore, Guimarães Jr (2016) also concludes that the demand for water in the São Francisco River basin region is 100% committed and that the UN recommendation of 1500 m³/inhab/year of water availability is overestimated. According to the author, this recommendation takes into account the use of water by industry, agriculture, and human and animal consumption. If it were intended only for human consumption, this recommendation would be 100 m³/inhab/year.

To reassess some of the criticisms made by Castro (2010), the TCU (2020) conducted an audit on some aspects of the PISF. The report verifies: (1) which works are still needed; (2) which municipalities have already installed capacity or need works to receive the PISF waters; (3) deadline and costs of the complementary works for the PISF to reach the municipalities; (4) current delivery condition of the works; (5) which are the current and future beneficiary cities by the PISF. The TCU (2020) estimates that about 33 complementary works will be necessary for the São Francisco River water supply to reach the targeted cities and the water supply systems to be integrated. The report estimates an expenditure of R$ 13.2 billion for the completion of these complementary works. Finally, the Court identifies deficiencies in the management of the PISF, such as lack of reliability of management information, little state participation in the management of the Project.

Empinotti, Gontijo Jr and Oliveira (2018) evaluate the PISF management process as centralized, in a Top-Down approach, where the federal government decides, manages, contracts or executes the work. According to the authors, this process of concentration of decisions by the federal government occurred due to two factors: (i) the technical and financial incapacity of state governments; and (ii) the decision of the committee with state participation for the use of PISF waters to be intended only for human or animal consumption.

By analyzing all these studies on the PISF together, it is possible to observe that they address an *ex-ante* debate about the project's assumptions, expected results and possible economic consequences. However, none of these studies evaluate *ex-post* the actual effect of public policy on society, and what are the economic and social consequences generated by the PISF on the benefited region. This study fills this gap by empirically analyzing the socioeconomic impacts achieved by the PISF, to evaluate its efficiency and effectiveness from the point of view of public resource allocation, as well as the convenience of its conclusion and expansion in the future.

4 Methodology

4.1 Average treatment effect on the treated

When a policy (treatment) affects an individual, that person acts according to his or her potential outcome for that treatment. Potential outcomes are hypothetical reactions that people would have if they are or are not exposed to a particular treatment. Thus, any person (i) has potential treatment exposure outcomes (Y_i^1) and non-exposure to treatment (Y_i^0). However, in practice we only see one of these outcomes, as the other is restricted to the theoretical world and tries to be represented by various methodologies.

One of the main objects of quasi-experimental econometrics is evaluation of the impact of an event or a policy on a group of people exposed to treatment, called the Average Effect of Treatment on the Treated (EMTT). This metric seeks to estimate the average of the differences in potential treatment and non-treatment outcomes on people exposed to the program ($T_i = 1$). Therefore,

$$EMTT = E(Y_i^1 - Y_i^0 | T_i = 1) = E(Y_i^1 | T_i = 1) - E(Y_i^0 | T_i = 1)$$

The fact is that $E(Y_i^0 | T_i = 1)$ can't be experienced, since we can't observe what a person's life would be like if he were untreated, after he has been exposed to treatment. To solve this issue, this field of econometrics works with two groups of people: the treatment group and the control group. The purpose is for the two groups to be identical, so that when looking at the actual outcome of one of the treatment or non-exposure groups, on average it would be the same as the expected potential outcome of the other group. Thus, a good control group is expected to be identical to the treatment group in both observable and unobservable characteristics, so that

$$E(Y_i^1 | T_i = 1) = E(Y_i^1 | T_i = 0) \text{ e } E(Y_i^0 | T_i = 1) = E(Y_i^0 | T_i = 0)$$

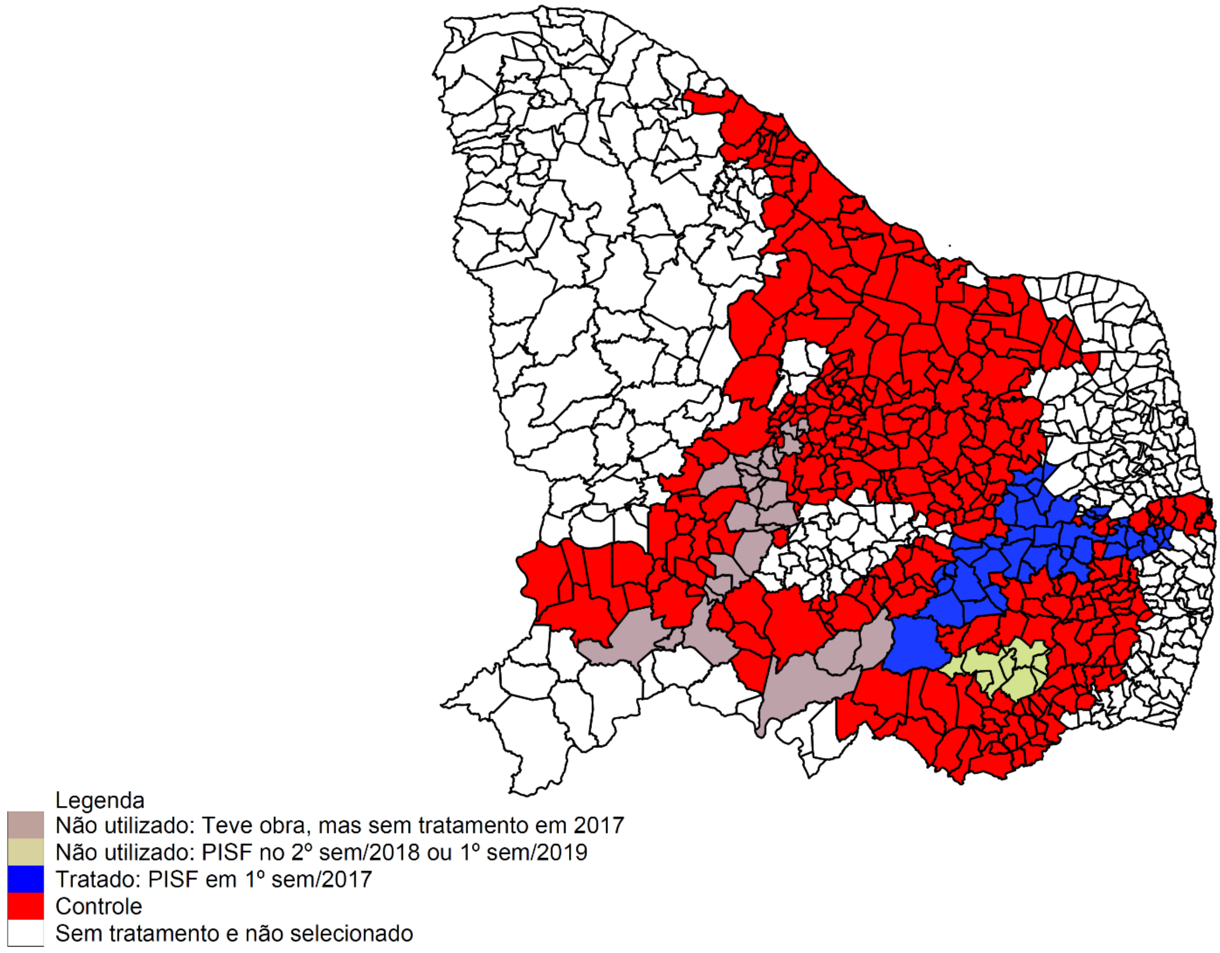
Thus, the EMTT could be estimated as follows:

$$\widehat{EMTT} = E(Y_i^1 | T_i = 1) - E(Y_i^0 | T_i = 0)$$

4.2 PISF control and treatment groups: Eligibility and *propensity score matching*

To evaluate the effects of the PISF on society, this evaluation considers as the treatment group the set of municipalities that received PISF waters as of the first half of 2017, through the Eastern Axis. In order not to suffer interference from the PISF itself in the control group and the estimated results, this evaluation excludes from the control group the municipalities that have undergone PISF works and the Pernambuco municipalities that received the PISF waters between the first half of 2018 and the first half of 2019. The list of municipalities and their classification is available in Annex 3. Figure 4 represents the location of these municipalities according to the treatment and control selection.

Figure 4 - Map of municipalities in the states of Rio Grande do Norte, Ceará, Pernambuco, and Paraíba, indicated if they are part of the treatment group (blue) and control (red).



Source: own elaboration.

This work considers two possible types of control groups. The first control group encompasses all other municipalities initially listed as eligible for the PISF, within the 390 municipalities initially planned, that did not receive the waters of the PISF until the year 2019 and that did not undergo the completion of works of the axes of the PISF.

This control group is appropriate because they are nearby municipalities, in the same region of the Northern Northeast, that have experienced the same expectation of being benefited by the PISF, and that suffer from the same conditions of scarce rainfall, high water evaporation, and low water availability. Thus, these municipalities are expected to have similar observable and unobservable characteristics as the municipalities in the treatment group. This is because the treated municipalities are differentiated from the control group municipalities by a geological issue that allowed them to receive water by being in the path of the waters transposed by the East Axis, i.e., an exogenous differentiation without self-selection.

However, it is possible to admit the criticism that there may have been some self-selection by some municipalities in the treatment group. It is possible that some municipalities have carried out works to adapt their water supply system to be previously in the path of the water transposed by the East Axis, before the PISF became operational. This hypothesis, although possible, is unlikely, because: (i) there could be uncertainty of the completion of the PISF works; (ii) there could be uncertainty about the actual location of the waters benefiting from the transposition, such as design changes due to geological virtues; and (iii) it presupposes a high long-term planning capacity of the state and municipal governments.

To minimize the effects of this criticism, this evaluation also works with a second control group: municipalities with similar observable characteristics, chosen by the *propensity score matching* (PSM) procedure.

The *matching* method attempts to find a control group that represents the treatment group based on observable characteristics. Thus, this method assumes that by finding individuals to form the control group with the same observable characteristics as the treatment group, they would also have similar unobservable characteristics. Put another way,

$$Y_i^0 \perp T_i | X_i$$

Thus, for the EMTT estimation, we have

$$\widehat{EMTT} = E(Y_i^1 | T_i = 1, X_i = x\ ) - E(Y_i^0 | T_i = 0\ , X_i = x\ )$$

The PSM was developed by Rosenbaum and Rubin (1983). It selects the control group based on the closeness of the probability that the municipalities are in the treatment group. Thus, it is necessary to first estimate the probability that the untreated municipalities are in the treatment group. To perform this procedure, this evaluation estimated the probit regression, as below:

$$Prob(Tratamento \mid X) = F(\beta_0 + \beta_1 Mortalidade\_Infantil + \beta_2 Area\_territorial + \beta_3 Tx\_escolaridade + \beta_4\ lnPIB + \beta_5 DIDHM\ +\ \beta_6 Esgotamento\ +\ \beta_7 Dummies\_UF\ + u)$$

All explanatory variables are from 2010, i.e., before treatment. Annex 1 presents the estimates of this equation and analyzes the common support condition, considered important for the validity of the method.

Table 1 tests the mean observables between the treatment and control groups, when the control group is composed of: (1) the eligible municipalities or (2) the municipalities selected by the PSM. All the mean estimates showed no statistically significant difference between the groups. This result corroborates that the treatment and control groups, by the two approaches, are similar and apparently adequate to evaluate the impacts of the PISF on society.

Table 1 - Mean test of observable variables between the translated and control groups, when the control group is composed of (1) eligible municipalities or (2) the municipalities selected by the PSM.

Variable	Group Type 1: Eligible Municipalities			Group Type 2: Municipalities with matching		
	Treaty	Control	Difference	Treaty	Control	Difference
Infant Mortality in 2010	13,708	15,629	-1,921 (-0,93)	14,027	13,369	0,658 (0,22)
Territorial area	360,660	390,910	-30,25 (-0,43)	357,960	344,650	13,31 (0,16)
Schooling rate in 2010	0,912	0,894	0,018 (3,20)	0,91179	0,912	0,001 (-0,04)
GDP in 2010	5770,400	5114,600	655,8 (2,41)	5519,700	5294,800	224,9 (0,72)
HDI in 2010	0,593	0,585	0,008 (1,16)	0,592	0,590	0,002 (0,23)
Depletion in 2010	0,013	0,016	-0,003 (-0,75)	0,013	0,012	0,001 (0,34)

Reference: *** p<0.01; ** p<0.05; * p<0.1. Values in parentheses correspond to the t-value of the difference. The PSM difference considered the weights estimated by the Epanechnikov (1969) Kernel function. Group 2 of treated municipalities is different because only municipalities with common support were selected.

4.3 Differences in Differences

According to the Guide to *Ex-post* Evaluation of Public Policies (Brazil, 2018), a naive first way to measure the impact of a policy is to ascertain difference in outcome between after and before treatment. This approach is inappropriate because all treated individuals in that society may have the outcome variable increased for other reasons contemporaneous to the policy. Thus, when looking at the before and after treatment group, the measured effect will be different from the desired one.

Another naive way of measuring the treatment effect of the policy is to measure the difference in outcome between two groups of people, treatment and control, only after the policy. This measure is simplistic when care is not taken to ensure that the control group is a group that adequately represents the treatment group[3]. Without these precautions, the outcome measure captures not only the effect of the policy, but may also capture a pre-existing difference between the two groups.

The Difference-in-Differences (DD) method unites these two naive metrics into a sophisticated measure with less strong assumptions than the methods presented above. Thus, it can first be specified in the calculation of the differences before and after treatment (when $t = 0$ e $t = 1$respectively) for each group, control and treatment. Subsequently, the estimate of the EMTT is obtained by the difference of these two differences, as specified below:

$$DD = \{E[Y_{it}|T_{it} = 1, t_{it} = 1] - E[Y_{it}|T_{it} = 1, t_{it} = 0]\} \\ - \{E[Y_{it}|T_{it} = 0, t_{it} = 1] - E[Y_{it}|T_{it} = 0, t_{it} = 0]\}$$

This method relaxes the assumption that there is a prior difference between the control and treatment groups. It allows the control group to be different from the treatment group if these different characteristics remain constant over time. The only assumption of DD is the assumption of parallelism before treatment, as pointed out by Foguel (2012, p. 75): it is assumed *"that the*

[3] When the control group adequately represents the treatment group, $E(Y_i^1|T_i = 1) = E(Y_i^1|T_i = 0)$ e $E(Y_i^0|T_i = 1) = E(Y_i^0|T_i = 0)$. Thus this measure is not simplistic and adequately measures EMTT.

temporal variation in the mean of the counterfactual of the treated group is equal to the observed variation in the mean of the control group", that is,

$$E[Y_{it}^0|T_{it} = 1, t_{it} = 1] - E[Y_{it}^0|T_{it} = 1, t_{it} = 0] \\ = E[Y_{it}^0|T_{it} = 0, t_{it} = 1] - E[Y_{it}^0|T_{it} = 0, t_{it} = 0]$$

To operationalize this method, this study estimates the treatment effect by measuring the parameter β_{DD} of the model below:

$$Y_{it} = \alpha + \gamma X_{it} + \rho T_{it} + \theta t_{it} + \beta_{DD} T_{it} t_{it} + \varepsilon_{it}$$

Where the parameter Y_{it} represents the outcome, variables tested in this evaluation. In municipal terms, the variable Y_{it} represents the quantitative Goat Herd, the value of Aquaculture Tilapia Production, the Planted Area, the value of Agricultural Production, the Liquidated Expenditure with Assistance Benefits, and the Total Realized Revenue. In individual terms of people residing in these municipalities, the variable Y_{it} represents the formal salary, the months of permanence in employment, and the occurrence of deaths from diarrhea[4].

It should be noted that it was not possible to estimate with statistical validity the municipal estimates of the effect of the PISF treatment. This occurred because the number of observations was small and made statistical tests unfeasible. The evaluation of these variables was carried out by graphical approach and has the purpose of analyzing preliminary evidence of the effect of the PISF on society. In parallel, the information at the person level (microdata) allowed sufficient statistical validity to perform the impact evaluation by Differences in Differences.

For the DD results estimated from microdata, this evaluation considers the year 2015 as before treatment and the year 2018 as after treatment. Annex 2 presents the annual estimates starting in 2013, which allows us to evaluate the annual treatment effect and to check the validity of the parallelism hypothesis before treatment.

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[4] ICD-10 codes: A00, A01, A03, A04, A06-09.

5 Data Source

This evaluation uses a series of databases to identify the effects of the PISF on indicators of agricultural production, livestock production, agricultural production, the formal labor market, and the health of the population benefited by the PISF.

Table 2 - Descriptive statistics of the pending variables

Variable	Database	Remarks	Average	Standard Deviation	Minimum	Maximum
Household with water supply (*dummy*)	PNADC/IBGE	1.3 million	0,9552	0,2068	0	1
Goat Herd (un.)	PPM/IBGE	7.105	5.661,3	16.016,6	20	337.000
Tilapia Production in Aquaculture (R$)	PPM/IBGE	502	1.1 million	7.5 million	0	102.0 million
Planted Area (ha)	MAP/IBGE	5.516	3.575,6	5.594,3	1	47.892
Agricultural Production (R$)	MAP/IBGE	5.5 million	5.3 million	14.6 million	0	24.0 million
Liquidated Expenses with Assistance Benefits (R$)	SICONFI/STN	2.481	217 thousand	867 thousand	50	18.0 million
Total Realized Revenue (R$)	SICONFI/STN	3.157	67.2 million	317.9 million	16,600	7.4 billion
Formal Salary (R$)	RAIS/ME	18.4 million	1.835,.97	2.733,18	203,40	142.0 thousand
Time in employment (month)	RAIS/ME	18.7 million	56,5	88,8	0	600
Death from Diarrhea (*dummy*)	DATASUS/MS	984.000	0	0,019	0	1

Source: own elaboration.

Table 2 presents the descriptive statistics of the variables used, as well as the databases from which the information was obtained. It describes the databases used and the other characteristics of the variables used.

5.1 Continuous National Sample Survey of Households - PNADC

PNADC is published by the Brazilian Institute of Geography and Statistics (IBGE) and aims to track quarterly and annual fluctuations in the country's labor force and socioeconomic development. This evaluation used bases from 2016 through 2019 of the following information from PNADC microdata at the household level: "S01007: What is the main form of water supply used in this household?" and "S01008: In the past 30 days, how often was water from the general network available to this household?"

Based on the answers of variable S01007, it was possible to assess whether the number of households served with regularized water supply increased. For this purpose, it was considered that the indicator "water supply was regularized" occurred with a value of 1 when the household received water from the general distribution network, from deep or artesian wells, or from shallow wells.

Based on the answers of variable S01008 it was possible to estimate if water became available more frequently to households located in the regions benefited by PISF waters.

It occurs that PNADC does not make it possible to identify the municipalities in the survey, except for the capital cities of each state. Thus, this evaluation compared the data from the state of Paraíba, the main beneficiary of the PISF in 2017, with the other states of the Northeast region, to assess whether there was any preliminary evidence of increased supply of water distribution.

5.2 Municipal Agricultural Production - PAM

PAM is published by IBGE and investigates a set of products from temporary and permanent crops in Brazil. The survey's collection unit is the municipality. This evaluation used the bases from 2010 to 2018 regarding the following information: the area planted or destined for harvest, in hectares; and the value of production of temporary and permanent crops, in thousand Reais.

5.3 Municipal Livestock Survey - PPM

The PPM is published by IBGE and investigates information on the number of animal species raised and livestock products, with the municipality as the collection unit. This evaluation used the bases from 2011 to 2018 regarding the following information: the value of tilapia production under aquaculture, in thousands of Reais; and the headcount of goat herds.

5.4 Public Sector Accounting and Tax Information System - SICONFI

SICONFI is released by the National Treasury Secretariat (STN) of the Ministry of Economy and is a tool for receiving and analyzing accounting, financial and tax statistics information from states and municipalities. This evaluation used the bases from 2011 to 2018 obtained from the Annual Accounts Statement regarding total realized revenue and liquidated expenses with social assistance benefits [5], per municipality, in reais.

5.5 Annual Social Information Report (RAIS)

RAIS is released by the Ministry of Economy (ME) and is a database of every formal employment relationship in Brazil, consisting of socioeconomic information reports sent by legal entities and other employers annually. This evaluation used information from the 2013 to 2018 bases on the length of employment in the employment relationship, in months; and on the value of the average annual salary, in reais.

5.6 Mortality Information System (SIM)

The SIM is released by DATASUS, which is the informatics department of Brazil's Unified Health System. The SIM registers mortality data, in a comprehensive way, to subsidize the various spheres of public health management. Its database has as its collection unit the death of each person. This evaluation used the databases from 2013 to 2018 regarding information on the ICD-10 codes of

[5] Detailed nature of expense codes: 33900600 and 33904800.

the underlying cause of death. Through this classification, it was possible to identify the ICD-10 codes related to diarrhea: A00, A01, A03, A04, A06-09.

6 Results

This paper analyzes the socioeconomic impacts achieved by the PISF regarding evaluating its effectiveness from the standpoint of allocation of public resources. The Difference-in-Difference's method is used on two types of control groups, comparing them with the municipalities that received treatment by the supply of the transposed waters of the São Francisco River.

As highlighted in the methodology section, it was not possible to statistically validate the DD estimates for the municipal databases. This occurred because the number of observations was small and made statistical tests unfeasible. For these outcome indicators, the evaluation occurred only in relation to the first control group, through a graphical approach, and had the purpose of analyzing preliminary evidence of the effect of the PISF on society. In parallel, the information with microdata collection unit, at the person levels, allowed sufficient statistical validity to perform the impact evaluation by Differences in Differences. Thus, the next subsection presents the preliminary results, whose collection unit is municipal. The second subsection performs the impact evaluation on the microdata.

6.1 Preliminary Results

Except for the first analysis below, the graphs in this section have a similar structure to the DD methodology, comparing the means of the treatment and control groups over time. The analysis focuses on: (i) checking whether the curves were parallel before 2016 (the last year without PISF water supply); and (ii) whether there was variation in the outcome for the treated group differently from the parallel projection of the control groups' outcome. This difference between the treatment and projection curves are equivalent to an average treatment effect estimate from the Difference-in-Difference's method, but without statistical significance. In this section, all the municipalities

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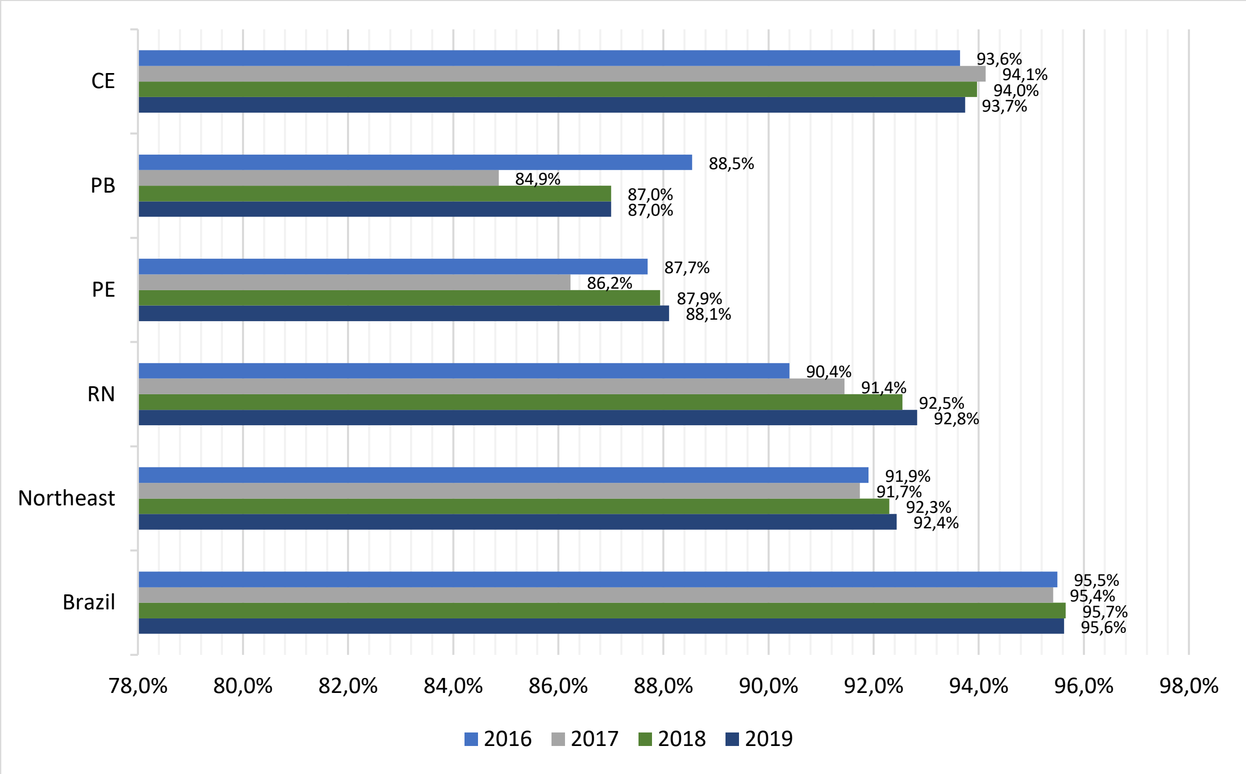
in the control group are type 1: those initially eligible for the PISF, but which did not receive the PISF waters and there was no construction of the axes within their territory.

6.1.1 Water supply

Before analyzing the socio-economic impacts achieved by PISF, it is necessary to understand whether the policy has been achieved in terms of its main objective: "to ensure adequate supply of good quality water, with guarantee, for the population and economic activities".

Figure 5 seeks to analyze whether the coverage of households with regularized water supply increased with the start of the PISF water supply. As the PISF began in 2017 for 43 of Paraiba’s municipalities, it would be expected that this state's water supply statistics would improve relative to the other states in the region and Brazil.

Figure 5 - Evolution of the percentage of households with piped or well water supply.

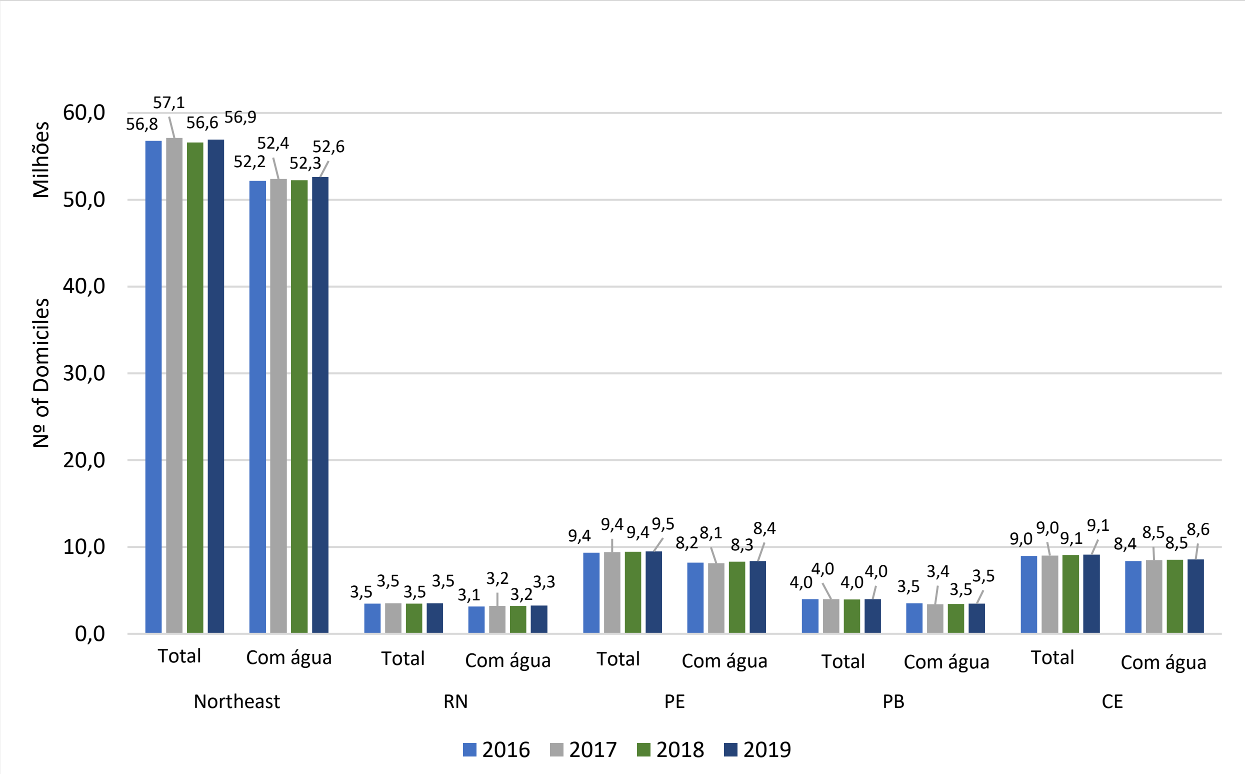


Source: Own preparation based on PNADC/IBGE data.

Figure 5 presents the evolution of the average percentage of households with regularized water supply in Ceará, Paraíba, Pernambuco, Rio Grande do Norte, the Northeast and Brazil. In Paraíba, water supply decreased in the first year of PISF, in 2017, and increased in 2018, at lower levels than in 2016. In the other regions, there was no significant variation very different from the state of Paraíba. Therefore, from Figure 5, it can be concluded that there was no relative increase in water distribution in the state of Paraíba because of the PISF

But this conclusion is still premature. There could have been an increase in the number of households that affected the results in percentage terms. To analyze this question, Figure 6 presents the evolution of the total number of households and households with normalized water supply. The conclusion is the same: there was no evidence that the PISF increased the coverage of water distribution in the state of Paraíba, because the numbers of households served did not increase and had a similar behavior to the other states in the region.

Figure 6 - Evolution of the number of households receiving piped or well water supply.



Source: Own preparation based on PNADC/IBGE data.

However, when the frequency of water supply is analyzed in terms of days of the week, the state of Paraíba has significantly increased the distribution of water in terms of frequency. Table 3 compares the frequencies of piped water supply between the state of Paraíba and the average of the Northeast region, opening the information by urban/rural region and by metropolitan region (and RIDE).

Table 3 - Average water supply frequency.

Local	Metropolitan Region of the Capitals	Type	2016	2017	2018	2019
PB	Outside the MR	Rural	3,62	3,42	5,44	5,34
	Outside the MR	Urban	3,66	3,98	5,33	5,20
	Within RM	Rural	6,57	6,30	7,00	6,76
	Within RM	Urban	6,68	6,77	6,70	6,63
Northeast	Outside the MR	Rural	5,25	5,16	5,32	5,17
	Outside the MR	Urban	5,07	5,03	5,32	5,30
	Within RM	Rural	5,87	6,07	6,47	6,43
	Within RM	Urban	6,23	6,20	6,24	6,25

Source: Own preparation based on PNADC/IBGE data.

From Table 3, the state of Paraíba strongly increased the frequency of water supply, in terms of days of the week, in the municipalities located outside the metropolitan region of João Pessoa, and slightly increased the frequency of water supply in the rural region within the metropolitan region of João Pessoa. This behavior was not observed in the Northeast region and even in Brazil.

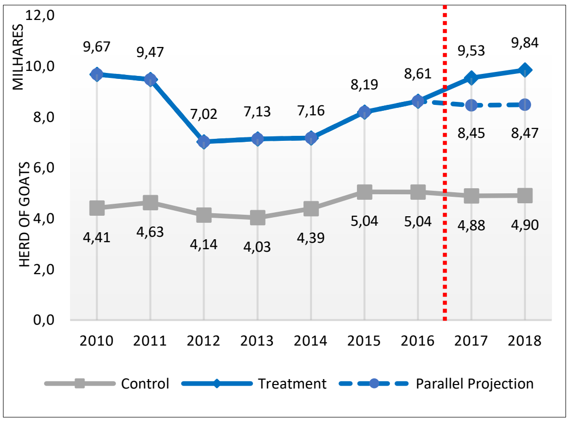
Therefore, there is preliminary evidence that the PISF has increased the frequency of water in terms of days, making water supply more stable for the population. The evidence shows that permanent water supply occurred in municipalities located outside the largest urban centers, such as rural regions and outside the metropolitan region of João Pessoa. However, there is no evidence that the PISF increased water supply coverage for households that were not previously served by the local water supply system.

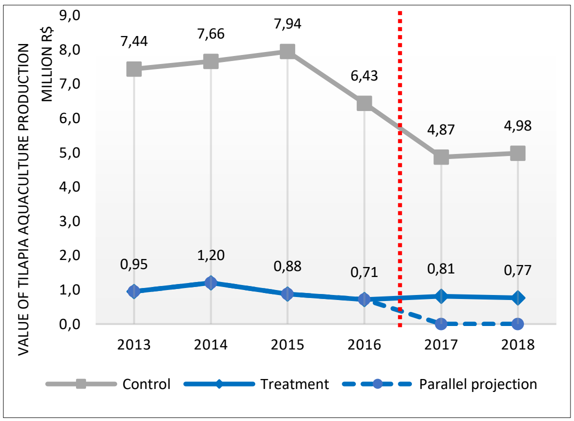
This result is consistent with the description of the policy supply in this pre-operation phase on the East Axis, where transposed waters from the São Francisco River took advantage of the previously installed local water distribution structure and ensured greater security and reliability in the region's water supply.

6.1.2 Livestock and aquaculture

Once it has been analyzed and evidenced that the increased supply of water from the PISF has generated results in the distribution of water in the regions first benefited by the PISF, the next analyses will be on the preliminary evidence of the effect of the PISF on society.

Figure 7 - Evolution of (left) goat herd and (right) average tilapia aquaculture production values by municipalities in the treatment and control groups.
Source: own preparation based on PPM/IBGE.



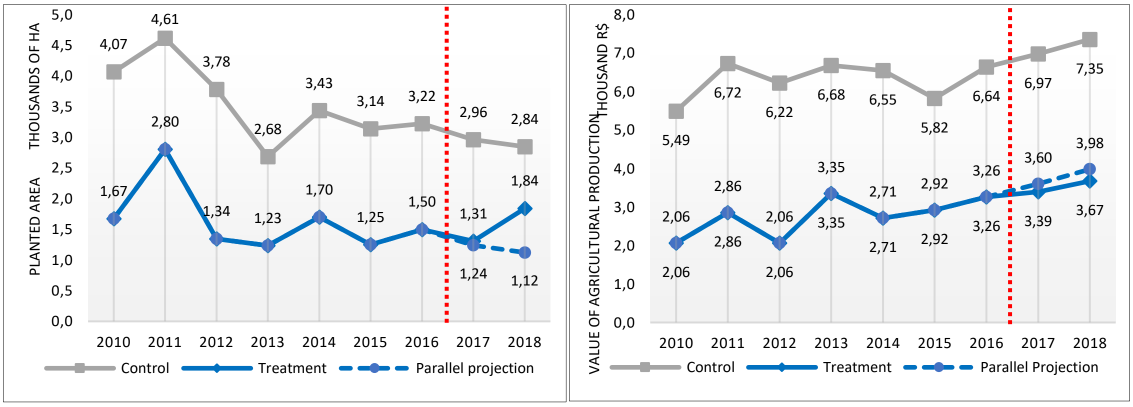


The graph on the left of Figure 7 shows the evolution of the average goat herd by municipalities in the treatment and control groups. Starting in 2012, the evolution of the treatment and control curves are parallel until 2016. The year 2017 marked the beginning of water supply by the PISF and the trends of the two curves stopped being parallel. These conditions are almost ideal for the validity of the DD method. From this graph, it is possible to see that there is preliminary evidence that the PISF has contributed to the increase in goat herd numbers in the region, around a thousand head per municipality. In other words, there is preliminary evidence of an increase in livestock production provided by the PISF.

The graph on the right of Figure 7 presents the evolution of the value of average tilapia aquaculture production by municipalities in the treatment and control groups. Aquaculture production has been defended by *ex-ante* evaluations of the PISF as a possible source of economic impact of the Project. However, from the graph, it is possible to see that the treatment and control curves were not parallel before the policy was offered. That is, it is not possible to obtain reliable estimates of aquaculture production, as there are other factors external to the PISF that have differentially affected the evolution of the treatment and control groups on aquaculture tilapia production. Therefore, there is no evidence of the influence of the PISF on aquaculture production.

6.1.3 Agriculture

Figure 8 - Evolution of (left) planted areas and (right) average agricultural production values, by municipalities in the treatment and control groups.



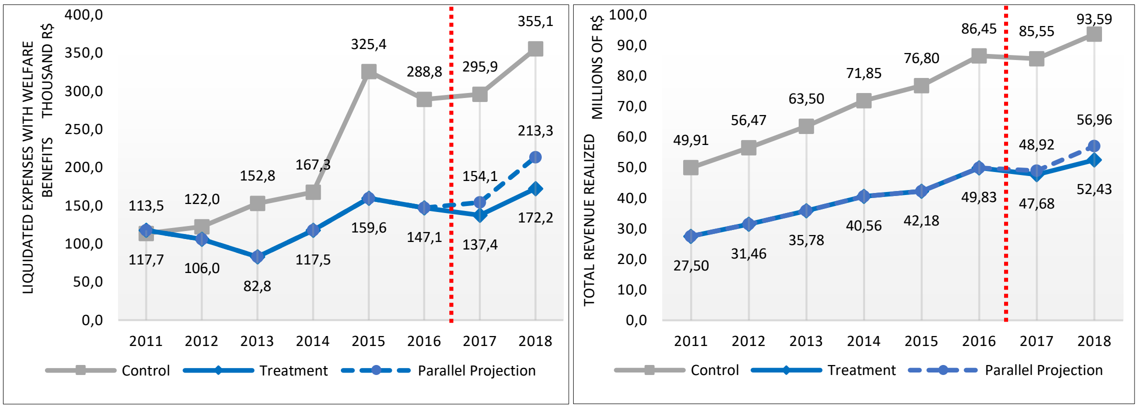
Source: own preparation based on PAM/IBGE.

The graph on the left of Figure 8 shows the evolution of the average planted areas by municipalities in the treatment and control groups. The evolution of the treatment and control curves are parallel until 2017. In 2018, there was a significant increase in the areas planted in the treated municipalities, in relation to the parallel projection of the evolution of the control curve. These conditions are ideal for the validity of the DD method. As the PISF started in 2017, the change in trend only in 2018 shows that the agricultural activity took a year to adapt and increase the exploitation of planted land. Therefore, from this graph, there is preliminary evidence that the PISF has contributed to the increase in the extent of planted areas used for agricultural production, by about 700 hectares per municipality.

The graph on the right of Figure 8 shows the evolution of average agricultural production values by municipalities in the treatment and control groups. From the graph, it is possible to notice that the treatment and control curves were not very parallel before the offer of the policy, but also did not have a very different behavior from the trends to the point of making the analysis unviable. However, the evolution of the treatment group curve did not differ much from the control group's parallel projection, showing a slight drop. Therefore, there is no preliminary evidence that the value of agricultural production increased with the PISF. Putting the two results together, one can sense that the area planted has increased, but the value sold of agricultural production has not. This may be due to several market factors, such as prices of the crops chosen, or because of the type of crop chosen in production. Finally, the preliminary result is interesting and needs more time to analyze if the value of production will follow the increase in planted area that occurred in 2018.

6.1.4 Public Accounts

Figure 9 - Evolution of (left) values of net expense with welfare benefits and of (right) values of average total realized revenue, by municipalities in the treatment and control groups.
Source: own preparation based on STN/SICONFI.



The left graph in Figure 9 shows the evolution of the values of net expenditure with average welfare benefits, by municipalities in the treatment and control groups. The reduction in drought coping expenses has been advocated by *ex-ante* evaluations of the PISF as a possible source of economic impact of the project. It is expected that the PISF will reduce local governments' drought-fighting expenditures. The evolution of welfare benefit expenditures seeks to create a *proxy* for these types of expenditures in municipal governments. However, the evolution of the treatment and control curves are not parallel before 2016. Therefore, it is not possible to obtain reliable estimates on the effect of welfare benefit expenditures, because there are other factors external to the PISF that have differentially affected the evolution of the treatment and control groups. Therefore, there is no evidence of the influence of the PISF on the reduction of drought combat expenditure.

The graph on the right of Figure 9 shows the evolution of average total realized revenue values by municipalities in the treatment and control groups. Another effect on local public accounts glimpsed in the *ex-ante* evaluations of the PISF is to increase the region's budget revenues.

According to ENGECORPS and HARZA (2000), the PISF would have an effect of increasing collected revenues, which would generate a greater supply of public goods and services and, consequently, increase the non-monetary income of families in the region. From the graph, the treatment and control curves are reasonably parallel before the start of the PISF. However, the evolution of the treatment group curve did not differ much from the control group's parallel projection, even showing a slight decrease. Therefore, there is no preliminary evidence that the amount of revenue collected from local governments increased with the PISF.

6.2 Impact Results

This section performs the impact evaluation on person-level microdata from RAIS/ME and SIM/DATASUS. Table 4 presents the impact estimates by the Difference-in-Differences method for the variables of the value of the monthly formal wage, the length of employment in the current attachment in months, and the probability of death from diarrhea-caused illness. Table 4 estimates the impact of the PISF by two different control group approaches: (1) municipalities initially eligible for the PISF, but which did not receive the PISF waters and no axis works were carried out within their territory; (2) municipalities chosen by the PSM procedure that have observable characteristics closer to the characteristics of the treatment group.

It is noteworthy that the period before the PISF was year 2015 and the period after was year 2018. Annex 2 presents the annual estimates starting in 2013 and analyzes the parallelism hypothesis before treatment. The findings of the average effect of the PISF can be interpreted by the coefficient estimates "Treaty X After 2017".

Table 4 - Difference-in-Differences Regression by Year.

	(1)	(2)	(3)	(4)	(5)	(6)
	Initially eligible municipalities			Municipalities with matching		
	Formal Salary	Time Employed	Death from Diarrhea	Formal Salary	Time Employed	Death from Diarrhea
i. Treaty	-133,146***	5,081***	0,000	-201,259***	-11,572***	0,000
	(6,969)	(0,211)	(0,000)	(6,618)	(0,257)	(0,000)
i. After 2017	416,555***	7,451***	0,000***	453,742***	7,382***	0,000
	(2,503)	(0,076)	(0,000)	(6,377)	(0,243)	(0,000)
Treaty X After 2017	-87,606***	-1,387***	-0,001**	-124,497***	-1,376***	-0,001*
	(9,971)	(0,302)	(0,000)	(10,655)	(0,376)	(0,000)
Constant	1783,792***	53,864***	0,000***	1852,798***	70,392***	0,000***
	(1,716)	(0,052)	(0,000)	(3,731)	(0,163)	(0,000)
Remarks	5.865.805	5.974.539	156.205	1.329.914	1.349.297	76.344
R^2	0,005	0,002	0,000	0,007	0,005	0,000

Source: Own elaboration. Note: (1) Coefficient estimate of the variable "Treated X After 2017" represents the average effect of treatment on those treated in the DD method. (2) values in parentheses are the standard errors of the coefficients. (3) Periods between 2015 and 2018 were compared. Reference: *** p<0.01; ** p<0.05; * p<0.1.

By the estimates, the average monthly formal wage of people residing in the treated municipalities decreased by somewhere between R$ 87 and R$ 124, representing a negative short-term effect of the Policy. Another negative effect of the PISF on the formal labor market occurred on the average time in employment. According to the estimates, the time spent in employment by people in the treatment group decreases by about 1.4 months after the PISF. Putting these two estimates together, we can conclude that the PISF has negative impacts on the formal labor market in the first years of implementation, as it tends to reduce wages and employability in the regions benefited by the policy. These effects, though small, are opposite to the desired effects in its planning phase and in the *ex-ante* evaluations.

The factors that explain these results are beyond the scope of this evaluation. However, it is worth noting that the analysis period after the PISF is very short (something over a year and seven months after the PISF was offered) and the results are still limited. A possible explanation may be due to the increase in planted area in agricultural regions. That is, there may be a displacement of labor from the formal market to agricultural plantations. If this occurs, it may explain the reduction in employability, because of the reduction in the labor supply by the worker. But these conclusions are not possible to be obtained by the present evaluation. Only with the publication of the new Census will it be possible to identify the municipalities and evaluate these effects.

Finally, Table 4 also estimates the effect of the PISF on the probability of death from diarrhea. The diseases related to these symptoms are strongly correlated to the condition of the local water supply. It is expected that with the PISF water supply, water quality will improve and increase the quality of life of the population. By the estimates, PISF was responsible for a 0.1 percentage point reduction in the incidence of diarrhea deaths. This estimate can represent a reduction in deaths of one to two people per year in each municipality benefiting from the policy.

7. Final considerations

This paper evaluates *ex-post* the economic and social consequences generated by the Integration Project of the São Francisco River with Watersheds of the Northern Northeast on the benefited society. This study empirically analyzes the socioeconomic impacts achieved by the PISF, after expenditures of around R$ 17 billion have been made since 2007, to assess its efficiency and effectiveness from the point of view of public resource allocation.

This evaluation finds preliminary evidence that PISF has not increased water supply coverage. However, PISF has increased the frequency of water distribution, in terms of days. The evidence shows that this permanent supply of water occurred in municipalities located outside the largest urban centers, such as rural regions and outside the metropolitan region of João Pessoa.

This result is consistent with the description of the policy supply in this pre-operation phase on the East Axis, where transposed waters from the São Francisco River took advantage of the previously installed local water distribution structure and ensured greater security and reliability in the region's water supply.

This work also finds evidence that the PISF contributed to an increase in livestock production, and in the extension of planted areas used in agricultural production. But this increase did not result in an increase in the value of agricultural production sold in the region benefiting from PISF waters.

Another positive effect of the PISF was the reduction in deaths due to diarrhea, showing an improvement in the quality of the water supply in the region.

On the other hand, this work estimated that the PISF has negative impacts on the formal labor market in the first years of implementation, as it tends to reduce wages and employability in the regions benefited by the policy. These effects, though small, are opposite to the desired effects in its planning phase and in the *ex-ante* evaluations. The factors that explain these results are beyond the scope of this evaluation and can be explored by future studies that analyze formal and informal activities in the region.

Finally, it should be noted that the analysis period after the implementation of the PISF is very short (something greater than one year and seven months after the PISF was offered until the available databases of 2018) and the results are still limited. A longer period of data collection is needed to obtain reliable information. Given the short window of analysis, we conclude that the significant positive results have already appeared and the negative results have low values, although some are statistically significant.

As for the analysis from the point of view of public resource allocation, it is noteworthy that if this evaluation were *ex-ante*, the recommendation would be not to perform the PISF. This is because it is possible to affirm that the project was not economically viable, since there was a significant increase in the previously estimated costs and a considerable increase in the initial period for completion of the works. These changes generated costs that exceeded the actual NPV value of R$ 1.8 billion estimated by ENGECORPS and HARZA (2000), which at 2019 prices would be R$ 7.5 billion.

As for the convenience of completing or expanding the PISF in the future, it is recommended that it be expanded, because the works on the axes have already been completed and to take advantage of the potential gains in scope by distributing these waters among the various municipalities in the region. It is noteworthy that despite the short period after the offer of the policy it has already been possible to obtain positive results on the economic and social consequences of the population benefited by the PISF. Therefore, the increase in the supply of water through the implementation of complementary works tends to generate an increasing economic and social effect.

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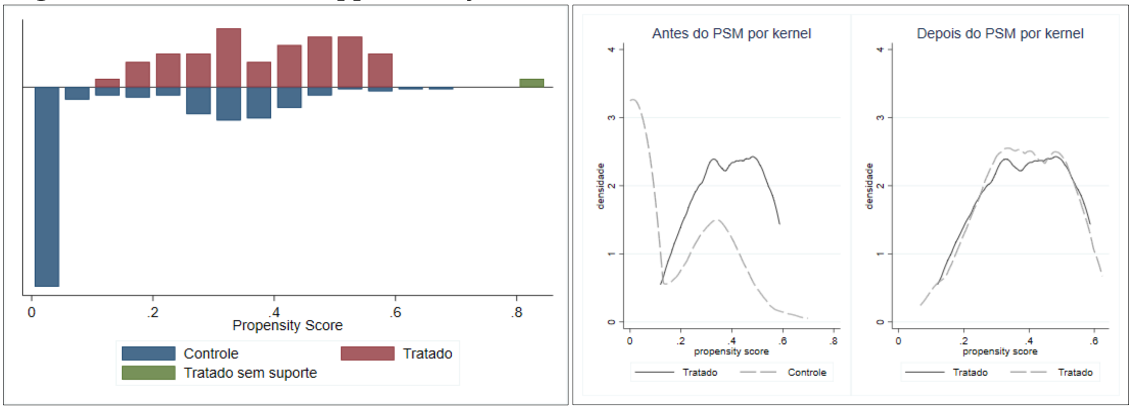
Annex 1 - Details of the estimation of the *Propensity Score Matching* method

Table A1.1 - Probit regression of the variable Treatment for the PSM procedure.

Treatment Probit	Coefficient
Infant Mortality in 2010	0.001
	(0.008)
Territorial area	0.001**
	(0.000)
Schooling rate in 2010	9.745**
	(4.275)
ln (GDP in 2010)	1.037
	(0.673)
HDI in 2010	-7.100*
	(4.191)
Depletion in 2010	0.402
	(4.567)
Pernambuco *Dummy*	-2.735***
	(0.811)
Constant	-14.212*
	(5.858)

Reference: *** p<0.01; ** p<0.05; * p<0.1.

Figure A1.1 - common support analysis, after PSM with kernel



Source: own elaboration.

According to the graphs in Figure A1.1, the common support assumptions of the PSM treaty groups were met, because in each propensity score stratum, for a treaty, there was at least one control group municipality with similar probability. When there was not, these treated municipalities were not considered in the sample. The graph to the right demonstrates how the kernel estimated weights weight the differences in the observable variables and make the *propensity score* measure similar between the treated and control groups after the PSM procedure.

Annex 2 - Yearly estimates of the Difference-in-Differences model

Table A2.1 Difference-in-Differences Regression by Year.

	(1) Formal Salary	(2) Time Employed	(3) Death from Diarrhea
i. Treaty	-118.994***	5.394***	0.001***
	(6.753)	(0.217)	(0.000)
i.2014	117.077***	0.259***	0.000
	(2.262)	(0.073)	(0.000)
i.2015	269.596***	2.715***	-0.000
	(2.279)	(0.073)	(0.000)
i.2016	450.820***	7.357***	0.000
	(2.327)	(0.075)	(0.000)
i.2017	608.578***	9.780***	0.000*
	(2.343)	(0.075)	(0.000)
i.2018	686.151***	10.167***	0.000**
	(2.350)	(0.075)	(0.000)
Treaty X 2014	2.652	-0.315	-0.001
	(9.414)	(0.302)	(0.000)
Treaty X 2015	-14.152	-0.313	-0.000
	(9.404)	(0.302)	(0.000)
Treaty X 2016	-54.491***	-0.781**	-0.001
	(9.521)	(0.305)	(0.000)
Treaty X 2017	-0.673	-1.167***	-0.001
	(9.525)	(0.305)	(0.000)
Treaty X 2018	-101.758***	-1.700***	-0.001***
	(9.510)	(0.305)	(0.000)
Constant	1514.196***	51.148***	0.000***
	(1.611)	(0.052)	(0.000)
Remarks	17801413	18085831	464152
R^2	0.008	0.002	0.000

Reference: *** p<0.01; ** p<0.05; * p<0.1

Table A2.1 presents the annual DD estimates and estimates of the parallel trends before treatment. The coefficient estimates for the variables "Treaty X 2014", "Treaty X 2015" and "Treaty X 2016" estimate the parallel trends. It can be seen except for the estimate of the year 2016 from model (1), all the estimates were without significance or with very small value. This result means that the estimates were parallel as the yearly slope changes were mostly statistically equal to zero. About the estimate of the year 2016 from model (1), despite being statistically different from zero, it had an estimated value of reduction of 54.49 Brazilian Reais in wages. This result was half of the estimated reduction in 2018, after the implementation of the PISF. This result may be an effect of the completion of the PISF works in its last year of construction. It would have to be further investigated among the beneficiary cities, but in principle, it does not invalidate the assumption of parallelism prior to the treatment of the DD model.

Annex 3 - Municipalities in the treatment and control groups

Table A3.1 - Classification of Municipalities, by Treatment Group - (Continued)

Municipalities	Group
Abaiara, Alto Santo, Aquiraz, Aracati, Aurora, Barbalha, Beberibe, Caririaçu, Cascavel, Caucaia, Cedro, Chorozinho, Crato, Eusébio, Fortaleza, Fortim, Granjeiro, Guaiúba, Horizonte, Icapuí, Icó, Itaiçaba, Itaitinga, Jaguaretama, Jaguaribara, Jaguaribe, Jaguaruana, Jardim, Juazeiro do Norte, Limoeiro do Norte, Maracanaú, Maranguape, Milagres, Missão Velha, Morada Nova, Ocara, Pacajus, Pacatuba, Palhano, Pindoretama, Porteiras, Quixeré, Russas, São Gonçalo do Amarante, São João do Jaguaribe, Tabuleiro do Norte, and Várzea Alegre	CE - Control
Alcantil, Aroeiras, Barra de São Miguel, Bayeux, Caldas Brandão, Caraúbas, Coxixola, Cruz do Espírito Santo, Fagundes, Frei Martinho, Gado Bravo, Gurinhém, João Pessoa, Mari, Massaranduba, Natuba, Nova Palmeira, Picuí, Puxinanã, Riachão do Bacamarte, Riachão do Poço, Riacho de Santo Antônio, Santa Cecília, Santa Rita, Santo André, São João do Tigre, São Sebastião do Umbuzeiro, Sapé, Serra Redonda, Sobrado, Taperoá, Tenório, Umbuzeiro, Zabelê, Aparecida, Areia de Baraúnas, Assunção, Belém do Brejo do Cruz, Bernardino Batista, Bom Sucesso, Bonito de Santa Fé, Brejo do Cruz, Brejo dos Santos, Cacimba de Areia, Carrapateira, Catolé do Rocha, Condado, Jericó, Joca Claudino, Junco do Seridó, Lagoa, Lastro, Malta, Marizópolis, Mato Grosso, Nazarezinho, Passagem, Patos, Paulista, Poço Dantas, Pombal, Quixaba, Riacho dos Cavalos, Salgadinho, Santa Cruz, Santa Luzia, São Bentinho, São Bento, São Domingos, São Francisco, São João do Rio do Peixe, São José da Lagoa Tapada, São José de Espinharas, São José do Brejo do Cruz, São José do Sabugi, São Mamede, Sousa, Várzea, Vieirópolis, and Vista Serrana	PB - Control
Afogados da Ingazeira, Agrestina, Águas Belas, Altinho, Angelim, Barra de Guabiraba, Bezerros, Bom Conselho, Bom Jardim, Bonito, Brejão, Brejinho, Brejo da Madre de Deus, Buíque, Caetés, Calçado, Calumbi, Camocim de São Félix, Canhotinho, Capoeiras, Carnaíba, Caruaru, Casinhas, Correntes, Cumaru, Cupira, Feira Nova, Flores, Frei Miguelinho, Garanhuns, Gravatá, Iati, Ibimirim, Ibirajuba, Iguaracy, Inajá, Ingazeira, Itaíba, Itapetim, Jataúba, João Alfredo, Jucati, Jupi, Jurema, Lagoa do Ouro, Lagoa dos Gatos, Lajedo, Limoeiro, Machados, Manari, Orobó, Palmeirina, Panelas, Paranatama, Passira, Pedra, Poção, Quixaba, Riacho das Almas, Sairé, Salgadinho, Saloá, Santa Cruz da Baixa Verde, Santa Cruz do Capibaribe, Santa Maria do Cambucá, Santa Terezinha, São Caitano, São João, São Joaquim do Monte, São José do Egito, São Vicente Férrer, Serra Talhada, Solidão, Surubim, Tabira, Taquaritinga do Norte, Terezinha, Toritama, Triunfo, Tupanatinga, Tuparetama, Venturosa, Vertente do Lério, Vertentes, Araripina, Bodocó, Carnaubeira da Penha, Cedro, Exu, Granito, Ipubi, Mirandiba, Moreilandia, Ouricuri, São José do Belmonte, Serrita, Trindade, and Verdejante	PE - Control
Acari, Açu, Afonso Bezerra, Água Nova, Alexandria, Almino Afonso, Alto do Rodrigues, Angicos, Antônio Martins, Apodi, Areia Branca, Augusto Severo, Baraúna, Bodó, Caiçara do Rio do Vento, Caicó, Caraúbas, Carnaúba dos Dantas, Carnaubais, Coronel João Pessoa, Cruzeta, Currais Novos, Doutor Severiano, Encanto, Equador, Felipe Guerra, Fernando Pedroza, Florânia, Francisco Dantas, Frutuoso Gomes, Governador Dix-Sept Rosado, Grossos, Ipanguaçu, Ipueira, Itajá, Itaú, Janduís, Jardim de Angicos, Jardim de Piranhas, Jardim do Seridó, João Dias, Jucurutu, Lagoa Nova, Lajes, Lucrécia, Macau, Marcelino Vieira, Martins, Messias Targino, Mossoró, Olho d'Água do Borges, Ouro Branco, Paraná, Paraú, Parelhas,	RN - Control

Patu, Pau dos Ferros, Pedra Preta, Pedro Avelino, Pendências, Pilões, Portalegre, Rafael Fernandes, Rafael Godeiro, Riacho da Cruz, Riacho de Santana, Riachuelo, Rodolfo Fernandes, Santana do Matos, Santana do Seridó, São Fernando, São Francisco do Oeste, São João do Sabugi, São José do Seridó, São Miguel, São Rafael, São Vicente, Serra do Mel, Serra Negra do Norte, Serrinha dos Pintos, Severiano Melo, Taboleiro Grande, Tenente Ananias, Tenente Laurentino Cruz, Tibau, Timbaúba dos Batistas, Triunfo Potiguar, Umarizal, Upanema, Venha-Ver, and Viçosa	

Table A3.1 - Classification of Municipalities, by Treatment Group - (Conclusion)

Alagoa Nova, Amparo, Barra de Santana, Boa Vista, Boqueirão, Cabaceiras, Camalaú, Campina Grande, Caturité, Congo, Cubati, Gurjão, Ingá, Itabaiana, Itatuba, Juarez Távora, Juazeirinho, Juripiranga, Lagoa Seca, Livramento, Matinhas, Mogeiro, Monteiro, Olivedos, Ouro Velho, Parari, Pedra Lavrada, Pilar, Pocinhos, Prata, Queimadas, Salgado de São Félix, São Domingos do Cariri, São João do Cariri, São José dos Cordeiros, São José dos Ramos, São Miguel de Taipu, São Sebastião de Lagoa de Roça, São Vicente do Seridó, Serra Branca, Soledade, Sossêgo, and Sumé	PB - Treatment
Sertânia	PE - Treatment
Alagoinha, Arcoverde, Belo Jardim, Cachoeirinha, Pesqueira, Sanharó, São Bento do Una, and Tacaimbó	PE - Treatment in 2nd Sem/2018 or 1st Sem/2019 (Not used)
Baixio, Barro, Brejo Santo, Ipaumirim, Jati, Lavras da Mangabeira, Mauriti, Penaforte, and Umari	CE - Where the work Occurred (Not used)
Bom Jesus, Cachoeira dos Índios, Cajazeiras, Monte Horebe, Poço de José de Moura, Santa Helena, São José de Piranhas, Triunfo, and Uiraúna	PE - Where Work Occurred (Not used)
Betânia, Custódia, Floresta, Parnamirim, Salgueiro, and Terra Nova	PB - Where Work Occurred (Unused)
José da Penha, Luís Gomes, and Major Sales	RN - Where the work occurred (Not used)

Source: own elaboration.