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SOCIO-ECONOMIC EFFECTS OF SÃO FRANCISCO INTER-BASIN WATER TRANSFER ON THE LOW-INCOME POPULATION

VITÓRIA ROBERTA MARTINS DE MELO GALINDO DE LIMA

RECIFE, JULY/2021

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Thesis submitted in partial fulfillment of the requirements for the degree of Master of Management and Rural Development in the Post-graduate Program of Management and Rural Development.

Area:	**Public Policies**
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PROGRAMA DE PÓS-GRADUAÇÃO EM ADMINISTRAÇÃO E DESENVOLVIMENTO RURAL

PARECER DA COMISSÃO EXAMINADORA DE DEFESA DE DISSERTAÇÃO DE MESTRADO

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To Josefa, Vítor, Terezinha and Guilherme.

"O sertanejo é, antes de tudo, um forte."
(Euclydes da Cunha)

ABSTRACT

Exploring the effects of water supply promoted by the São Francisco Inter-basin Water Transfer (PISF) on socio-economic aspects is relevant for three main reasons. First, water is crucial for the local development. Second, there was a large volume of resources employed. Finally, many people were affected by the project. For filling a literature gap, this research proposes to verify those impacts on the low-income population living in municipalities that received water from PISF in 2017. To reach this purpose, we applied the Differences in Differences identification method for three different control groups, considering 2016 as the year before treatment and 2018 as the year after treatment. We investigated the effects on individual income, on whether the person had a paid work or not, on family income, and the participation in the *Bolsa Família* Program. The main results imply that, in the short term, the project has generally played a positive role in low-income population lives. However, the observed improvement on the analyzed variables does not necessarily mean an increment in family well-being.

Keywords: *PISF; Impact Assessment; Low-income Population.*

RESUMEN

Explorar los efectos del abastecimiento de agua promovido por la Transferencia de Agua Intercuencas de São Francisco (PISF) sobre los aspectos socioeconómicos es relevante por tres razones principales. Primero, el agua es crucial para el desarrollo local, después, se empleó un gran volumen de recursos y, finalmente, muchas personas se vieron afectadas por el proyecto. Para llenar un vacío de literatura, esta investigación propone verificar esos impactos en la población de bajos ingresos que vive en municipios que recibieron agua del PISF en 2017. Para alcanzar este propósito, se aplicó el método de identificación de Diferencias en Diferencias para tres grupos de control diferentes, considerando 2016 como año anterior al tratamiento y 2018 como año posterior al tratamiento. Investigamos los efectos sobre los ingresos individuales, sobre si la persona tenía un trabajo remunerado o no, sobre los ingresos familiares y sobre la participación en el Programa *Bolsa Família*. Los principales resultados implican que, en el corto plazo, el proyecto en general ha jugado un papel positivo en la vida de la población de bajos ingresos. Sin embargo, la mejora observada en las variables analizadas no significa necesariamente un incremento en el bienestar familiar.

Palabras clave: *PISF; Evaluación de Impacto; Población de Bajos Ingresos.*

CONTENTS

1 INTRODUCTION

Water insecurity concern more in the Northeast of Brazil because the semiarid climate occurs in most of this region. The sparse and badly distributed rainfall, as well as frequent droughts, turned surviving in semiarid a difficult task for its inhabitants. Historically, the populations handled this situation by migrating to richer regions or to larger cities on the coast. As people go to these areas with no guarantee of employment or a minimum condition for living, they end up in slums. On the other hand, politicians tried to manage the situation, constructing water reservoirs. However, as the region also presents a high evaporation index, reservoirs finish up losing much water (INTEGRAÇÃO NACIONAL, 2000; BRAZIL, 2004).

The São Francisco Inter-basin Water Transfer (PISF) appears in these circumstances as a permanent solution for that water scarcity. By constructing channels that transport the water from this great river to certain basins, the government aimed to guarantee the volume of rivers that supply municipalities affected by droughts. The availability of water, combined with essential factors, should provide all the needed conditions for the region to develop socially and economically. Based on technical studies, the government designed this scenario as a measure to overcome migration and the attempt to store water (INTEGRAÇÃO NACIONAL, 2000; BRAZIL, 2004; MOLINAS, 2019).

Government planned the transbasin diversion to work through two main channels, named the North Axis and the East Axis. The latter is the focus of this research since it started to be operated first, in 2017. At the beginning of 2020, it had already benefited 1.4 million people through the supply of 46 municipalities in the states of Paraíba and Pernambuco (BRASIL, G. do, 2020), and the expectation is to assist 3.1 million more people when it is fully operating (NABUCO, 2019). Its initial budget was at R$ 3.1 billion[1] (BRAZIL, 2004), but in 2018 the investment prediction was already at R$ 4.3 billion (PLANEJAMENTO, 2018).

Previous works have already explored some East Axis social and economic impacts. Correia (2019), Silva, Diniz, and Medeiros (2020) and Gonçalves, Gonçalves, and Costa (2021) investigated the process of deterritorialization and community reorganization amidst the channel construction. Ribeiro (2021) had an approach on the changes in social capital, while Costa and Ojima (2020) worked on the dynamics of the migratory flow to the benefited region. Finally, Santos (2020) evaluated the effects on household provision of water, agricultural production, the number of deaths due to diarrhea, formal wages, and employability. Nevertheless, from the best of our knowledge, none of the preceding researches considered the start of the East Axis operation to measure its causal effect by focusing on low-income population aspects.

So far, we described the PISF objectives, the importance of water in the region as a potential

[1] Amount adjusted by the Extended Consumer Price Index (IPCA) from the Brazilian Institute of Geography and Statistics (IBGE) having as starting date December 2003 and ending date June 2018.

factor for socio-economic development, how many people it affected, as well as the volume of resources employed. Given that, the evaluation of this project is relevant not only for Brazil but also for other countries where water scarcity constitutes one of the most relevant challenges. That said, this research aims to fill the gap in the literature by answering the following question: what are the socio-economic impacts of receiving water from the East Axis of PISF on vulnerable people?

To achieve that goal, this work has as general objective to identify the effects of receiving water from PISF on social and economic outcomes for low-income population at the individual and household levels. This general objective has specific goals: identify how the selection process of municipalities to receive the project's waters took place; discern which municipalities have already received water from the project and in which year; model the data using the proposed econometric strategy; and analyze the results in the light of the region's socio-economic reality.

As for the econometric strategy, we are proposing the use of the Differences in Differences (Diff-in-Diff) approach. Although government choose municipalities based on objective criteria as mentioned before, we believe that it is still possible to have a source of endogeneity in the choice process, as it is not completely random. When we apply the Diff-in-Diff strategy, we are comparing municipalities that receive or do not receive water from the project, in two moments: the year before and the year after receiving this water. This way we are mitigating this source of endogeneity by controlling for observable and non-observable variables before treatment. Other authors used approaches such as the general equilibrium and input-output models and the paired t-test to assess the effects of accessing water (GAO; YU, 2018; PENG et al., 2020; BHATTI et al., 2019). However, the nature of the available data that we worked with (pooled cross section at the individual and family levels) fitted better the Diff-in-Diff modelling.

This thesis is organized as follows. In the next section, we give the PISF background and an overview for the current scenario. In section 3 we debate other works that investigated the effects of water transfer constructions. Then, in section 4 we detail the methodological framework and the procedure limitations. In section 5 we present the results, we discuss them, and we show the robustness checks we performed. Finally, in section 6 we present the conclusion.

2 SÃO FRANCISCO WATER TRANSFER BACKGROUND AND OVERVIEW

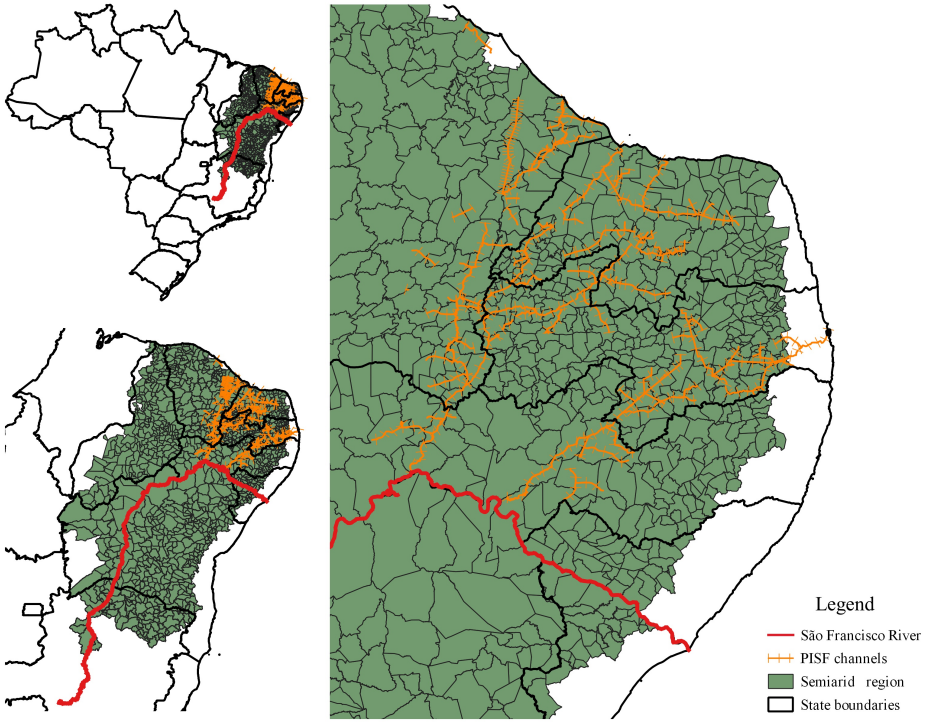
One of the oldest ideas for solving the problem of water scarcity in the Northeast of Brazil is to build a large-scale structure of water diversion involving the São Francisco River Basin. Castro (2009) describes successive moments throughout Brazilian history in which government designed and archived this type of project. The first of them was during the emperor Dom Pedro II regime, in 1847, when an engineer and deputy from Ceará, a state in the Northeast region, presented a proposal, but nothing was done. Since then, another five attempts have been made to approve and execute the inter-basins water transfer constructions. However, according to Molinas (2019), it was

only in the late 1990s and early 2000s that the federal administration proposed what comes closest to the São Francisco Inter-basin Water Transfer (PISF) current design.

The project targets the Semiarid region, which is constituted of 1262 municipalities and correspond to approximately one-fifth of the national territory. To be included in the Semiarid, a municipality have to fit in three criteria[2] that involve short rainfall rate, high dryness, and considerable water deficit (SUDENE, 2017). These characteristics result in a poor hydrography and insufficient water availability to continuously sustain the rivers' flow (ÁGUAS, 2018). This water shortage makes it impossible to survive in dignified conditions, generating hunger and misery (SOARES, 2013). Despite that, this area is home to about 27 million inhabitants (IBGE, 2017c).

Figure 1 shows where the Semiarid territory, the São Francisco River and the PISF are located in Brazil.

Figure 1: Semiarid region, São Francisco River and PISF locations in Brazil.



Source: own construction based on data from IBGE and CBHSF.

The PISF most recent design started to be created during the government of the former president Fernando Henrique Cardoso (FHC) (1995-2002). At the beginning, the authorities in charge

[2] An average annual rainfall equal to or less than 800 mm, the Thornthwaite Dryness Index equal to or less than 0.50, and a daily percentage of water deficit equal to or greater than 60%, considering all days of the year.

of the PISF initiative were politically related to Campina Grande, the largest city in the *Agreste*[3] of the State of Paraíba. To prevent any hint of political favouritism arising from this fact, the government signed an agreement with the National Institute for Spatial Research (INPE) for them to independently develop technical studies on the project (MOLINAS, 2019).

At the end of the studies, the project faced strong resistance because of environmental issues. For regulatory agencies, the studies in this field were still incipient. Therefore, except for this, FHC administration conclude the PISF project in 2000 (MOLINAS, 2019). With water provision, the government aimed to develop tourism, agribusiness, textile, clothing, leather, footwear, and other industries. In addition, they intended to support the industrial complex at the *Suape* Port, in the State of Pernambuco. It was also expected an increase in irrigable spots and the creation of job positions, especially in rural zones. With this dynamization in the local economy, they predicted a growth in GDP. These conditions would create a good scenario for reducing rural migration toward urban areas, diminishing expenses with drought and improving population's health (INTEGRAÇÃO NACIONAL, 2000). However, pushed by political, financial and circumstantial reasons, FHC gave up from the project one year later[4] (SÃO PAULO, 2001).

In 2003, Lula's administration resumed the efforts to implement the PISF. Finally, one year later, documents that measure the construction environmental impacts[5] filled some blanks in this field. However, the National Water Agency (ANA) determined human consumption to be the prioritization of water use, instead of reaching several areas as proposed in the original project. The Agency restricted pumping for other purposes to the surplus period in the São Francisco Basin (ANA, 2005). Under these conditions, the project had its approval in 2004. Three years later, the project works started (MOLINAS, 2019).

The engineers structured the project around two main channels called North Axis and East Axis. Each axis would capture water from a certain point on the São Francisco River and divert the flow to supply other basins in the States of Paraíba, Pernambuco, Ceará, and Rio Grande do Norte. Thus, the water transfer would keep the volume of rivers and reservoirs suitable to face droughts. Initially, the government expected to benefit at least 390 municipalities with regular water provision, reaching 12 million people until 2035 (DESENVOLVIMENTO REGIONAL, 2020).

Ten years after the construction beginning, the East Axis started operating. This axis in-

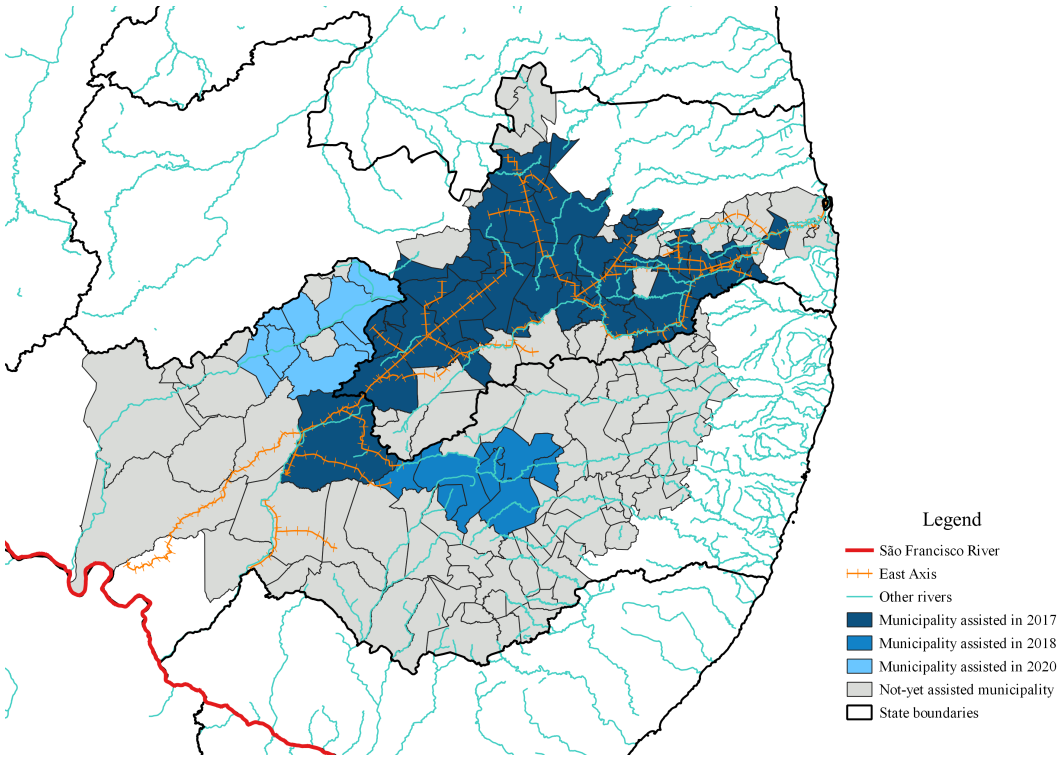
[3] Transition zone between the Coastal Forest and the Semiarid region.

[4] Brazil was experiencing energy rationing, and transferring water from São Francisco at that time would mean a loss in the capacity of energy generation through hydroelectric plants that use the river's water. In addition, there was a change in the head of the Ministry of Integration, responsible for the project. The new one had no interest in the project or an electoral base in the Northeast. There were still conflicts between politicians from the water donor States (Bahia, Sergipe and Alagoas) and the recipient States (Pernambuco, Ceará, Rio Grande do Norte and Paraíba). As the elections were close, the government felt that it would be counterproductive to start a giant construction with no guarantee that the next president would support its continuation. Finally, FHC stated that the government had no resources available to invest in the PISF.

[5] Environmental Impact Study (EIA) and Environmental Impact Report (RIMA).

tended to supply the Agreste of the State of Pernambuco and Campina Grande (MOLINAS, 2019). According to the state agencies responsible for the project management, 64 municipalities have already received water from this axis[6]. Figure 2 illustrates the PISF East Axis, as well as the municipalities that have already received water from the project, in which year they received it, and the 109 ones that will still receive it.

Figure 2: East Axis and status of municipalities assistance in PISF.



Source: own construction based on data from IBGE, CBHSF, COMPESA, and CAGEPA.

The context of starting the axis operation was a severe drought that had been hitting some municipalities for almost three years. In addition to the removal of these cities from the emergency, there are reports of a noticeable improvement in water quality. However, some rural communities and smaller towns in the region maintain the routine of drought due to lack of plumbing or because they are unreachable of the dams (SÃO PAULO, 2018).

Another side of the construction is the resettling of 848 families. This process involved the dissolution of territory identity, scarcity of water for agriculture and animals, loss of land, psychological issues such as depression, deforestation of sacred trees for indigenous people and

[6]We had the information about when and which municipalities received the treatment by contacting Paraíba and Pernambuco governments through the Access to Information Law (LAI).

even the abandonment of children by construction workers. In addition, the arrival of workers in the channels construction spots brought problems such as the encouragement of child prostitution (DOMINGUES, 2019).

Two years after the beginning of the operation, the stretches of transposition continue to be the focus of conflicts relating to water management. There are oppositions between large and small agricultural producers, industries, riverside communities, fishermen, miners, governments, cities, and four hydroelectric power plants dams (*Três Marias, Sobradinho, Itaparica and Paulo Afonso*). Although state governments and, secondarily, local supply companies were previously in charge of the water management, there is still much discordance about who has access to the resource, who pays for it and how much (OLIVEIRA, 2019).

Given this scenario, we were curious about how people with less bargaining power over the project benefits were receiving the effects of the water transfer. Then, we decided to investigate the PISF impacts on the vulnerable population. As for a part of this measurement process, in the next section, we explore more deeply what are the outcome expectations for water-based development projects. We also discuss other works that have tried to assess the socio-economic impacts of water provision, mainly through water transfer projects, focusing on the PISF East Axis.

3 LITERATURE REVIEW

Young and Loomis (2014) state that, currently, there are many problems related to water all around the world. Floods and droughts, groundwater basins overexploited, bad quality of water among other issues have been pushing society to create good solutions for well managing this resource. The unique characteristics of water such as its hydrological and physical attributes and the size of the demand lead the good to not be traded in the regular market. Because of that, governments need frequently to interfere with this good usage.

In the sense of the expected outcomes of these eventual interventions, Young and Loomis (2014) say that public policies related to water supply can impact households, communities, farms or business firms. Howe and Easter (2011) complement this thought, stating that in the long term, water transfer may affect the regional economy and even the national economy.

Gopalakrishnan (1973) talks about the necessity of studying the changes in the pattern of water usage to better understand their impacts on economic growth. Also on this subject, Brewer (1964) states that to well evaluate water transfers in terms of economic growth, it is necessary to understand the entire transferring process. This involves how the actors involved relate to each other, as well as the investments used to execute the project and maintain it. In any case, an increase in income is expected, whether at the individual, regional or national level.

Starting with the empirical analyses, Gao and Yu (2018) assessed the effect of the South-to-North Water Diversion Project of China on Beijing's economy using input-output analysis. The

results pointed to an increase in the gross value added of the industries, with emphasis on the water and environment conservation, and social security sectors. Peng et al. (2020) analyzed the socio-economic impacts of the same project in Beijing as well but from the perspective of the computable general equilibrium model. The authors simulated two scenarios, one with the volume of water promoted by the diversion and the other with little or no volume of water from this source. As a result, they found that the project absence would imply a decrease in the gross regional product, in the proportion of high water consumption industries, in employment, and disposable income per person. Following the same reasoning, they observed an increase in the price index and unemployment.

Bhatti et al. (2019), on the other hand, assessed the socio-economic impacts of having access to water through dams in the Sindh region of Pakistan. Using the paired t-test, the researchers found evidence pointing to an improvement in almost all the more than ten variables studied. Among the results, we highlight the increase of 36.16% in income, 17.68% in consumption and 32.15% in savings. They also observed a 19.9% reduction in migration.

As for the São Francisco Inter-basin Water Transfer (PISF) East Axis context, Correia (2019), Silva, Diniz, and Medeiros (2020) and Gonçalves, Gonçalves, and Costa (2021) followed the same case study method to investigate the effects in the municipality of Monteiro, on the Pipipã indigenous people and the Vila Lafayette Rural Community, respectively. The three authors found signs of deterritorialization in the families that had to be relocated because of the channel construction. In addition, many of these families continued to have difficulty accessing water, even after the axis started operating.

Ribeiro (2021) investigated, through a case study, how PISF affected the Cariri region. The results found in this research pointed that groups excluded from water access would remain excluded after the transfer execution. More than that, the project contributed to increasing pre-existing inequalities or generating new inequalities or conflicts around water. However, the relationship between affected people and communities has grown stronger, although their ties with local institutions have not been strengthened.

Santos (2020) came closer to what this study proposes to do. Using the Differences in Differences strategy, its research investigated the impact of receiving water through the East Axis of PISF on socio-economic variables. The evidence suggested as positive effect an increase in the frequency of water supply, livestock production and the amount of planted areas, and a decrease in deaths due to diarrhea. On the other hand, the results showed a negative effect on wages and employability. Finally, the findings indicate a null effect on the value of agricultural production and the number of households with water provision.

A particularity of this research is that we are focusing on low-income families. In this sense, it is important to investigate who is being most affected by the effects of the program in terms of gender. This is because, according to OECD (2010), in poorer families, women are better able to

manage money to promote the family's well-being.

Therefore, the literature tells us that there are various socio-economic effects of water transfer. Normally, they are expected to be positive, as increased access to water is expected to boost the economy. However, in the case of the São Francisco River, it is still not clear what is the average effect of this policy on the low-income population. That is what this dissertation intends to discover using the following methodological approach.

4 METHODOLOGICAL PROCEDURES

4.1 DATA

To achieve our goal, we mainly explored *Cadastro Único* (CadUnico) dataset, a product of a federal instrument that identifies and characterizes low-income families in Brazil. From this dataset, we choose as outcome variables[7] individual income from work, person with paid work in the last 12 months, family income, and participation in *Bolsa Família* Program[8]. In our estimations, we were controlling municipal and household characteristics in all outcomes, and personal characteristics when the outcome was at the individual level.

To control municipal characteristics, we used variables from different sources. From the Brazilian Institute of Geography and Statistics (IBGE), we set dummies to identify population size classes of municipalities[9] and dummies to indicate the federated unit that each observation belonged to. From the Institute of Applied Economic Research (IPEA), the Agronomic Institute of Pernambuco (IPA), and the Executive Water Management Agency of Paraíba (AESA) we used the average annual rainfall. Still from IPEA, we acquired information about altitude and distance from the municipality to the capital of the federated unit that the municipality is part of. We also used the distance from the municipality's centroid to the river in the nearest point. This last variable we calculated based on georeferenced data that IBGE and the São Francisco River Basin Committee (CBHSF) made available.

As for the household characteristics, we only selected information already available in CadUnico. We used a dummy that distinguishes whether the household is located in a rural area or not. We also calculated the number of children per household, considering children everyone aged 16 years old or less[10].

[7] We normalized the revenue outcomes using the neperian logarithm. The other outcomes assume a value of zero or one, depending on their status.

[8] *Bolsa Família* is a federal program which gives financial aid to families in poverty (monthly income between R$89.01 and 178 R$ per person) and extreme poverty (monthly income up to R$ 89 per person) situation in Brazil. Participating in the program is subject to the presence of pregnant women and children or adolescents between 0 and 17 years old in the family composition. Continuing in the program depends not only on income, but also on compliance with other requirements, such as school attendance and keeping children up to date with vaccinations (FEDERAL, n.d.)

[9] We set these classes based on IBGE classification (IBGE, 2017b).

[10] We decided for this cut-off because this is the age at one can legally start working in most types of occupation in

When it comes to individual income from work and probability of working, we controlled the following personal characteristics: skin colour, gender, and education level. All this information is available at the CadUnico dataset, so we only had to make some transformations. First, we turned the skin colour and the gender variables into dummies that identify whether the person has white skin colour or not and whether the person is a man or not, respectively. As for the education level, we assigned discrete and increasing numbers to the standardized schooling in Brazil[11].

Table 1 summarizes the control and treatment variables, their sources and uses.

Table 1: Summary of variables.

Source	Variable	Use
CadUnico	Individual income from work.	*Outcome*
	Person with paid work in the last 12 months.	
	Family income.	
	Participation in *Bolsa Família* Program.	
	Rural area.	*Control*
	Number of children.	
	Skin colour.	
	Gender.	
	Education level.	
IBGE	Population size classes.	
	Federated Unit.	
IPEA	Average annual rainfall.	
	Altitude.	
	Distance from the municipality to the capital of the federated unit.	
IPA	Average annual rainfall.	
AESA	Average annual rainfall.	
Own calculation based on IBGE and CBHSF	Distance from the municipality's centroid to the river in the nearest point.	

Source: own construction.

4.2 COMPOSITION OF TREATMENT AND CONTROL GROUPS

In order to compose our control and treatment groups, we decided to follow government's decision about which municipality was supposed to receive water from the river deviation. Regarding the treatment group, this was a simple task, since we have no other choice besides selecting municipalities that were benefited until December 2017. Given that CadUnico information is avail-

Brazil (BRASIL, 1998).

[11] Starting at number zero for illiterate, one for pre-school, and so on, up to six for post-secondary education.

able only from 2012 up to 2018, we excluded from our sample municipalities that received water in 2018 to not contaminate the results with any effect that could be captured in these municipalities.

Concerning the control group in our main strategy, we selected municipalities that the federal government had chosen to receive the PISF[12], but had not received it until 2018. We call this the *not-yet treated* group. However, we arranged two other control groups to be part of our robustness checks.

To check for the consistency of the PISF local effects, we first opted for testing the use of a second control group. This group we call *near enough*. For composing the *near enough* control group, we chose municipalities in the same micro-region[13] of those municipalities that received the water in 2017.

Continuing with the analysis, we also employed a third control group. The criteria for pre-selecting municipalities to compose this last group was based on municipalities that: a) belong to a different Federated Unit from those that were or will be benefited by the project; and b) belong to the semiarid region. In order to calibrate the probability of receiving treatment, we used the propensity scoring matching (PSM). With this strategy, we could increase the chances of municipalities in this group to be located distant enough to not receive spillover effects, but still be similar in social and geographic[14] terms. We call this group *far enough*.

Table 2 briefly describes each of the groups we used, as well as the number of municipalities (designated by n) in each group.

Finally, after performing the estimations with each control group, we also performed the exercise of removing from the sample municipalities with large populations and/or that were capitals of the federated units. This exercise allowed us to identify if, at some point, the reality of large cities was driving the results. This is also a way of removing from the sample cities that, because of their population - and, as consequence, electoral - size, might have eventually exerted some political pressure, unknown by official sources, to receive the project.

That said, the number of observations we were working with depended on each regression model. We will present this information in each table of results in the next section.

[12]The list of municipalities that are supposed to receive water from the river deviation is available at the Ministry of Regional Development (MDR) website (DESENVOLVIMENTO REGIONAL, 2020).

[13]IBGE division to group municipalities with similar social, environmental and economic dynamics (IBGE, 2017a).

[14]As for social characteristics, we used a combination of social factors such as Human Development Index (HDI), poverty, population size, and part of population living in rural areas from IPEA. From the Annual Social Information Survey (RAIS) database we took the number of employes in industry, agriculture, footwear, and textile sectors. Regarding geographic characteristics, we used the same variables we described in section 4.1.1, but having only IPEA as source of information. We only used information for the years 2000 or before them because the studies carried out to support the choice of beneficiary municipalities took place during this period.

Table 2: Summary of treatment and control groups.

Group	Description	n
Treated	Receives water until December 2017.	49
Not-yet treated	Receives water after 2018.	117
Near enough	May receive or not water after 2018. Located in the same micro-region of Treated.	32
Far enough	Won't receive water at all. Located in different Federated Units of Treated. Similar geographic and socioeconomic characteristics of Treated.	623

Source: own construction.

4.3 CHOICE OF IMPACT ASSESSMENT STRATEGY

From a methodological perspective, when we aim to measure the impact of an exogenous interference in an unit of interest we would ideally be able to submit it to experience two different situations at the same time. This way we would be able to precisely measure the effect of receiving treatment since everything is the same but the status of receiving treatment. However, in non-experimental settings as we have in this research, we can only observe one of the situations at a time. Either an unit is receiving the treatment or it is not. Considering this reality, researchers use alternative approaches for impact assessment, such as the Differences in Differences (Diff-in-Diff) method (FOGEL, 2016; WOOLDRIDGE, 2015).

The intention of this approach is to control observable and unobserved characteristics when trying to measure the impact of a treatment. To do this, we need information about the control and treated groups before and after treatment and perform a double difference with the outcomes. In the case of PISF, we believe that characteristics such as the political level of influence of local economic agents may be in the error term as an unobserved variable and relate to the main explanatory variable. By applying the Diff-in-Diff, we can mitigate the effects of this possible source of endogeneity.

One of the main assumptions of Diff-in-Diff is that before treatment, both treated and untreated groups share the same trajectory (FOGEL, 2016; WOOLDRIDGE, 2015). To check if PISF fits in this assumption, we performed a T-test with the outcome variables for the treated group against each non-treated group (see Table 3).

This test makes us able to check for any statistically significant difference (designated by

Table 3: T-test for outcomes in each control group.

	N	Treatment	Control	Diff.	t
Treaded vs Not-yet treated					
Individual income from work	47,324	7.85	7.15	-0.70	42.26
Paid work	534,961	0.22	0.21	-0.01	9.98
Family income	187,350	4.27	3.74	-0.53	48.89
PBF participation	187,377	0.58	0.67	0.09	33.07
Treaded vs Near enough					
Individual income from work	32,810	7.87	6.80	-1.06	60.03
Paid work	160,187	0.22	0.17	-0.05	24.15
Family income	56,537	4.27	2.78	-1.49	81.72
PBF participation	56,540	0.58	0.71	0.14	31.50
Treaded vs Far enough					
Individual income from work	414,587	7.87	7.20	-0.67	70.46
Paid work	1,769,168	0.22	0.23	0.01	10.13
Family income	604,723	4.27	3.98	-0.29	29.68
PBF participation	604,776	0.58	0.62	0.04	16.86

Source: own calculation.

Diff. on Table 3) on outcome variable means for treated and control group before treatment[15]. The module of t-statistic in the last column of Table 3 shows that there was no significant difference in mean between treatment and control groups before treatment for any analyzed variable. This reinforces that Diff-in-Diff is a good approach for modelling the data we are going to use.

4.4 MODELLING

As mentioned earlier, for the empirical strategy, we applied the Differences in Differences method. We used this technique to identify the average treatment effect on the treated (ATT). To do so, we estimated the difference between treated and untreated groups' expected outcome values after and before treatment (FOGEL, 2016; WOOLDRIDGE, 2015; CALLAWAY; SANT'ANNA, 2021). Equation (1) details this operation, where Y denotes the outcome variable, T denotes the unit treatment status (T=1 if treated and T=0 otherwise) and t denotes a point in time (t=1 for the period after the intervention and t=0 for the period before the intervention).

$$ATT = \{E[Y|T=1,t=1] - E[Y|T=1,t=0]\} - \{E[Y|T=0,t=1] - E[Y|T=0,t=0]\}, \tag{1}$$

Since the project started operating in 2017, we set 2016 as the year before treatment and 2018 as the year after treatment. Therefore, we had a dummy for time assuming 0 when year was equal to 2016, and 1 when year was equal to 2018. First, we made this variable to interact with

[15] In the first column after variable names, N indicates the number of observations.

a dummy for treatment, this last one assuming value 1 whether the family or person have lived in a municipality that received the water from PISF until December 2017 (treatment group), and 0 otherwise (control group). In a second step, we had two additional regressions for each outcome at the individual level, in which we added a second categorical variable. These categorical variables indicate whether the PISF affects household heads or their partners.

We made that distinction because, given the way CadUnico is designed[16], we assume that most heads of household would be women, while most partners would be men. Thus, the average effect of receiving water on family heads is a way of getting closer to the project impact on women responsible for the household.

Therefore, depending on the outcome variable level, the model can assume up to three different specifications, as follows:

$$Y = \theta T + \phi t + \alpha DID + \lambda X + \varepsilon; \tag{2}$$

$$Y = \theta T + \phi t + \alpha DID + \beta DID_{hoh} + \lambda X + \varepsilon; \tag{3}$$

$$Y = \theta T + \phi t + \alpha DID + \beta DID_{partner} + \lambda X + \varepsilon \tag{4}$$

where *Y* is the socio-economic variable of interest, *T* is the treatment dummy, *t* is the time dummy, *DID* is the interaction between treatment and time dummies, DID_{hoh} is the interaction between treatment, time and head of household dummies, $DID_{partner}$ is the interaction between treatment, time and partner dummies, *X* is the set of control variables, and ε is the error.

The parameters of interest are α and β, since they denote the average treatment effect on the treated group. The estimates for these parameters will show us the average effect of receiving water from PISF on low-income families or people, in comparison to others that lived in very similar municipalities, but were not benefited by the project.

4.5 LIMITATIONS

There are two main limitations of this study, both regarding the CadUnico dataset that is immediately available.

The first concern is that the government expected the project effects to appear in the long term. However, the dataset available about low-income families in Brazil only allows us to conduct a short-term analysis. The years at one's disposal so far are from 2012 up to 2018. But the first benefited municipalities received water from the São Francisco river in 2017. Therefore, we require

[16]Prioritizing women to be designated as the head of household, so they can directly receive the transfer from *Bolsa Família*.

to access information including more years after the year of treatment to make a more appropriate analysis in this sense.

The second constraint is that despite we are using microdata at the individual and household levels, we may be dealing with a pooled cross-section dataset. Even though there is a unique identifier for each household and person, the government releases the dataset on an annual basis, and identifiers change randomly every year. Moreover, CadUnico operators can exclude families or people from the dataset once they no longer meet the requirements to be there. Therefore, we can not know if we are tracking the same family or person year by year. This dataset characteristic forbids us to reduce the bias of omitting any variable in the model, especially if it is fixed over time. Reducing this bias could provide more accuracy to our findings.

These limitations, nonetheless, do not diminish the research relevance. From the perspective of impact assessment on socio-economic aspects, it is an innovation for the literature to identify the effects of receiving water from PISF. Having one year worth of data after treatment already allows us to assess the project first impacts if there are any. More than that, performing the regressions using a pooled cross-section is enough to achieve our goals in this research.

5 RESULTS AND DISCUSSION

In this section, the following tables show the effects of receiving water from the river transferring on the outcome variables. These are individual income from work and person with paid work in the last 12 months (designated by *Paid work* on the tables), at the individual level; and family income and family participating in *Bolsa Família* Program (designated by *PBF* on the tables), at the household level.

In the first columns of each outcome variable, we see the average effect of living in a municipality that received water from PISF on the population (designated by *DID* on the tables). In the second and third columns, for the outcomes at the individual level, we distinguish that average effect for the heads of household and their partners, respectively (designated by *DID hoh, partner* on the tables).

P-values are in parentheses, right below the estimates. It is also possible to check the R squared that shows how much our modelling adjusts to the data.

Finally, in each table, we present two panels. Panel A contains the results including all municipalities in the given treatment and control groups. In Panel B, we are showing the results that we obtained excluding large municipalities from the sample. Keeping in mind these changes from one panel to another, all regressions share the same treatment group. In this sense, changes from one table to another only occur in the control groups.

We decided for presenting the results of the regressions in which we used all the corresponding controls. We had the understanding that these results are more complete because they carry the

singularities of each person and household, respecting the level of analysis.

5.1 MAIN STRATEGY

Table 4 exhibits the results we obtained in our main strategy of impact assessment. In other words, setting the *not-yet treated* as the control group.

Table 4: PISF effects on socio-economic outcomes (main strategy).

	PANEL A (all municipalities)							
	Individual income from work				**Paid work**		**Family income**	**PBF**
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(1)
DID	0.089***	0.268***	0.037	-0.018***	-0.025***	-0.043***	0.104***	-0.015***
	(0.00)	(0.00)	(0.23)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
DID hoh, partner		-0.260***	0.185***		0.013***	0.197***		
		(0.00)	(0.00)		(0.00)	(0.00)		
R^2	0.219	0.220	0.219	0.162	0.162	0.165	0.185	0.162
N	89,897	89,897	89,897	1,004,712	1,004,712	1,004,712	369,129	369,159
	PANEL B (excluding large municipalities)							
	Individual income from work				**Paid work**		**Family income**	**PBF**
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(1)
DID	0.014	0.280***	-0.106**	-0.009**	0.004	-0.040***	0.138***	-0.015***
	(0.70)	(0.00)	(0.01)	(0.03)	(0.37)	(0.00)	(0.00)	(0.00)
DID hoh, partner		-0.432***	0.336***		-0.027***	0.225***		
		(0.00)	(0.00)		(0.00)	(0.00)		
R^2	0.105	0.106	0.105	0.143	0.143	0.145	0.114	0.122
N	60,623	60,623	60,623	752,078	752,078	752,078	273,241	273,261
Controls	YES	YES	YES	YES	YES	YES	YES	YES

* p<0.100, ** p<0.050, *** p<0.010.

Note 1: in Panel B, the municipalities of João Pessoa, Campina Grande and Caruaru were excluded. Note 2: in the first columns of each variable (1), we expose the average effect of receiving water from the PISF only on the general public (*DID*). In the second columns of the variables *individual income from work* and *paid work* (2), we expose in the first lines the average effect of receiving water from the PISF on the general public (*DID*) and in the second lines the effect on the head of household (*DID hoh*) . In the third columns of the variables *individual income from work* and *paid work* (3), we expose in the first lines the average effect of receiving water from the PISF on the general public (*DID*) and in the second lines the effect on the partner of the head of household (*DID partner*).

Source: own calculation based on data from CadUnico, IBGE, IPEA, IPA, AESA, and CBHSF.

In Panel A, the results showed an average increase of 8.9% on individual income from work for people living in municipalities that received water from PISF. However, the effect is negative for the heads of household (decrease of 26%) and positive for their partners (increase of 18.5%). We also observed an increase of 10.4% in family income that may have one of its sources the individual income from job. Nevertheless, when we analyzed the paid work outcome, we saw that the population is 1.8 times less likely to work. Yet, heads of household and their partners were 1.3 and 19.7 times more likely to work, respectively. Finally, when it comes to participation in *Bolsa Família*, families were 1.5 less likely to participate in the program.

In Panel B, where we have the results excluding large municipalities from the sample, we lost the statistical significance on individual income from work for the population. Regarding the effect on heads of household and their partners, the estimates remained negative for the former, positive for the later, and statistically significant for both, although they present greater intensity. Analyzing paid work, we found that in smaller cities, people are 0.9 times less likely to work. An improvement of 0.9 percentage point if compared to the result in Panel A. When we focus on heads of household, paid work becomes negative when we restrict the analysis to smaller municipalities. As for the partners, the effect on paid work only became higher. We also noticed an increase in the magnitude of family income, which we may attribute in parts to income from work, especially that from the partners. The participation in the *Bolsa Família* program did not change from one panel to another.

Before proceeding with this analysis, we have to keep in mind that, in this sample, approximately 87% of the household heads are women, while almost 90% of partners are man. Returning to what we saw in the previous paragraphs, we perceived a general improvement in all outcome variables but paid work. However, when we take a deeper look on individual income from work, we see that women are not the ones taking more advantage from this general improvement, no matter where they are. The fact that they live in assisted municipalities also decrease their chances of working once they are in small cities.

We hypothesize that this finding may be happening because men are getting better-paid jobs in treated municipalities. Thus, other family members may no longer be required to work. We also speculate that this may be associated with a deep-seating culture of women staying at home to take care of their children and their houses. Accordingly, the results that diverge from the expected positive effects permeate fields that we did not choose to focus on in this research. In other words, to confirm or deny these suppositions, we need further analysis on the labour market and on the culture of low-income families in the exploited municipalities.

5.2 ROBUSTNESS CHECKS

For checking the solidity of local effects of receiving water from PISF, we performed the regressions also using two other control groups. Table 5 shows the results we obtained setting up *near enough* as the control group. Table 6 presents our findings when taking *far enough* as the control group.

In Table 5, most results remained statistically significant. However, we see now an average increase of approximately 19% in individual income from work for the population in general in both panels. The effects remained negative on the income of heads of household (decrease of 29.6% in Panel A and 37.2% in Panel B), but at a greater intensity. The signs' maintenance also occurred for the income from work of the partners (increase of 21.2% in Panel A and 27.8% in Panel B).

Table 5: PISF effects on socio-economic outcomes (robustness check 1).

	PANEL A (all municipalities)							
	Individual income from work			**Paid work**			**Family income**	**PBF**
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(1)
DID	0.194***	0.341***	0.095**	-0.005	-0.016***	-0.044***	0.142***	-0.010***
	(0.00)	(0.00)	(0.01)	(0.14)	(0.00)	(0.00)	(0.00)	(0.00)
DID hoh, partner		-0.296***	0.212***		0.028***	0.248***		
		(0.00)	(0.00)		(0.00)	(0.00)		
R^2	0.373	0.375	0.374	0.188	0.189	0.202	0.316	0.214
N	59,568	59,568	59,568	299,597	299,597	299,597	110,483	110,486
	PANEL B (excluding large municipalities)							
	Individual income from work			**Paid work**			**Family income**	**PBF**
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(1)
DID	0.198***	0.382***	0.06 7	-0.005	-0.003	-0.048***	0.142***	-0.011
	(0.00)	(0.00)	(0.09)	(0.14)	(0.40)	(0.00)	(0.00)	(0.13)
DID hoh, partner		-0.372***	0.278***		-0.006*	0.269***		
		(0.00)	(0.00)		(0.08)	(0.00)		
R^2	0.200	0.203	0.201	0.150	0.150	0.166	0.162	0.127
N	37,518	37,518	37,518	220,172	220,172	220,172	79,368	79,370
Controls	YES	YES	YES	YES	YES	YES	YES	YES

* p<0.100, ** p<0.050, *** p<0.010.

Note 1: in Panel B, the municipality of Campina Grande was excluded. Note 2: in the first columns of each variable (1), we expose the average effect of receiving water from the PISF only on the general public (*DID*). In the second columns of the variables *individual income from work* and *paid work* (2), we expose in the first lines the average effect of receiving water from the PISF on the general public (*DID*) and in the second lines the effect on the head of household (*DID hoh*) . In the third columns of the variables *individual income from work* and *paid work* (3), we expose in the first lines the average effect of receiving water from the PISF on the general public (*DID*) and in the second lines the effect on the partner of the head of household (*DID partner*).

Source: own calculation based on data from CadUnico, IBGE, IPEA, IPA, AESA, and CBHSF.

On the other hand, when we assess paid work, the effect is not significant on the population. In Panel A, heads of household are 2.8 times more likely to work and their partners 24.8 times. In Panel B, this same outcome variable becomes negative (-0.6) when compared to heads of household in not assisted municipalities. Paid work for partners remains positive, but becomes higher, in the magnitude of 26.9. The effect on family income is the same in both panels, at an increase of 14.2%. As for the *Bolsa Família* Program, in both panels, participating in the program is negative and is around 1. However, in the second panel, the estimate is not statistically significant.

In Table 6, the effect on individual income from work for general people becomes statistically non-significant. As for the heads of household and their partners, the estimates' behaviour follows that of the previous tables. The effect is negative for the heads of households and positive for their partners, increasing the intensity from one panel to another. Paid work also remains negative for the general people. In panel A, it is not significant for the heads of household, but in panel B it remains negative and significant (-4.8). In both panels, paid work is positive for the partners and is set around 22. Using this new control group, the effect is positive on family income is positive

Table 6: PISF effects on socio-economic outcomes (robustness check 2).

	PANEL A (all municipalities)							
	Individual income from work				**Paid work**		**Family income**	**PBF**
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(1)
DID	-0.009	0.103***	-0.059***	-0.010***	-0.012***	-0.042***	0.045***	-0.006*
	(0.51)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.09)
DID hoh, partner		-0.200***	0.125***		0.004	0.218***		
		(0.00)	(0.00)		(0.12)	(0.00)		
R^2	0.208	0.208	0.208	0.183	0.183	0.184	0.144	0.175
N	735,679	735,679	735,679	3,175,808	3,175,808	3,175,808	1,126,559	1,126,621
	PANEL B (excluding large municipalities)							
	Individual income from work				**Paid work**		**Family income**	**PBF**
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(1)
DID	0.010	0.154***	-0.093***	-0.004**	0.014***	-0.041***	0.043**	-0.011**
	(0.63)	(0.00)	(0.00)	(0.04)	(0.00)	(0.00)	(0.04)	(0.02)
DID hoh, partner		-0.296***	0.216***		-0.048***	0.233***		
		(0.00)	(0.00)		(0.00)	(0.00)		
R^2	0.161	0.161	0.161	0.176	0.176	0.176	0.130	0.165
N	653,934	653,934	653,934	2,874,901	2,874,901	2,874,901	1,018,210	1,018,263
Controls	YES	YES	YES	YES	YES	YES	YES	YES

* p<0.100, ** p<0.050, *** p<0.010.

Note 1: in Panel B, the municipalities of Teresina, Campina Grande and Feira de Santana were excluded. Note 2: in the first columns of each variable (1), we expose the average effect of receiving water from the PISF only on the general public (*DID*). In the second columns of the variables *individual income from work* and *paid work* (2), we expose in the first lines the average effect of receiving water from the PISF on the general public (*DID*) and in the second lines the effect on the head of household (*DID hoh*) . In the third columns of the variables *individual income from work* and *paid work* (3), we expose in the first lines the average effect of receiving water from the PISF on the general public (*DID*) and in the second lines the effect on the partner of the head of household (*DID partner*).

Source: own calculation based on data from CadUnico, IBGE, IPEA, IPA, AESA, and CBHSF.

in both pannels, showing an average increase around 4%. The participation in the *Bolsa Família* program is negative and significant in both panels, indicating that families living in municipalities that received water from PISF are 0.6 or 1.1 less likely to participate in the program.

What robustness tests tell us is that the results observed in them are subtly different from those found in the main strategy results. Most of these changes revolve mainly around the intensity of the results. In robustness tests, we observed effects of greater magnitude. Considering the years we are analyzing, this means that the short-run effects are clearly localized in treated municipalities.

6 CONCLUSION

Through this work, we aimed to identify the effects of receiving water from the São Francisco Inter-basin Water Transfer (PISF) on low-income families and individuals. To achieve this goal, we first sought to understand the dynamics of project implementation and the choice of municipalities. We then realized that the differences-in-differences strategy fit perfectly to the context and nature

of our data, albeit with certain limitations.

Analyzing the results, we observed an increase in individual and family income, in having a paid work for those responsible for the household, and a smaller number of families participating in *Bolsa Família*. It implies that, in the short term, PISF has played a positive role in low-income population lives. However, according to how CadUnico was designed, most heads of households are women. Therefore, the results also indicate that men are being the greatest beneficiaries of PISF. This finding led us to believe that income increases are not necessarily welfare improving, since women better manage the money in low-income families.

The robustness checks showed that the short-term local benefits are clear and persistent in different control groups. However, we believe that over time we will probably see more spread of the effects. The dynamization of the economy in benefited municipalities may impact their neighbourhood in the following years.

To complement the findings of this research, we suggest a deepening of the effects of the PISF on the labour market of which low-income people are part. A better understanding of the culture of these families would also be recommended for checking the hypotheses raised about why the heads of families worked less in the benefited municipalities.

For the upcoming studies, we intend to explore also the long-term impacts once data is available for years after 2018. More than that, we aim to ask for the CadUnico identified database, which should allow us to study the project effects using other methodological approaches. Furthermore, we expect to analyze the PISF effects on other health indicators through DATASUS[17] database.

[17]IT Department of Brazilian Unified Health System. It is an agency responsible for collecting, processing and disseminating health information.

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